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PHOTOGRAPHS OF BROOKS' COMET (OCT. 17, 1893).

E. E. BARNARD

On the morning of the 17th of October W. R. Brooks, of Geneva, N. Y., discovered a small comet in the constellation Virgo, some ten degrees west of the star Epsilon. The comet was very low on the eastern horizon, and though not visible to the naked eye, it was quite bright as a telescopic object. It had a small nucleus and a short tail, but presented no features essentially different from the average telescopic comet.

The writer, having been engaged since the absence of the September moon in photographing the Milky Way, was prepared to photograph this new comet if possible.

On the morning following its announcement the position of the comet was carefully measured with the twelve-inch equatorial for the benefit of the early computers of its orbit. There was nothing, as seen in this telescope, to suggest any special results in photographing it, especially as the comet could only be seen for about half an hour and was badly obscured by the dense atmosphere near the horizon. However, on the morning of the 19th it was decided to try a plate, and an exposure of half an hour was given—from the time the comet could first be seen above the horizon until dawn cut it out.

The resulting photograph was highly satisfactory, as it showed features not seen in the twelve-inch. The comet presented a straight tail, nearly four degrees long, with two minor rays springing out from each side of the head for a short distance and making a considerable angle with the main tail.

The next morning was cloudy, but on the morning of the 21st another exposure of half an hour was given. Nothing new was shown on this picture, but the features were all more strongly marked, especially the ray from the northern side of the head, which now appeared as a short, broad tail. The main tail was straight and presented a rather graceful appearance.

On the morning of the 22d the twelve-inch showed that some disturbance had occurred, as the tail near the head was distorted. The customary exposure of half an hour was given with the Willard lens. To say the least the resulting picture was astonishing.

It presented the comet's tail as no comet's tail was ever seen before. The graceful symmetry was destroyed; the tail was shattered. It was bent, distorted and deflected, while the larger part of it was broken up into knots and masses of nebulosity, the whole appearance giving the idea of a torch flickering and streaming irregularly in the wind. The short northern tail was swept entirely away and the comet itself was much brighter.

The very appearance at once suggested an explanation which is probably the true one. If the comet's tail in its flight through space had suddenly encountered a resisting medium which had passed through the tail near the middle, we should have precisely the appearance presented by the comet. It is not necessary that the medium should be a solid body; if it possessed only the feeblest of ethereal lightness it would deflect, distort and shatter the tail. What makes this explanation all the more probable is that the disturbance was produced from the side of the tail that was advancing through space. But there is no known body or bodies in that part of the heavens. If, therefore, the explanation is the true one, this comet points out the existence of a hitherto unknown body or substance in the neighborhood of the sun—a swarm of meteors, a mass of exceedingly attenuated cosmical matter. It cannot be of much density, or it would have shown on the plate. Such matter is not an unreasonable supposition since it has long been suspected that some unknown influence of this kind exists near the Sun and disturbs the motion of the perihelion of Mercury.

I am speaking of this comet as if it were near the sun. This is an assumption that may be wholly erroneous. It is apparently near the sun, but in reality may be a vast distance beyond, although that is hardly probable. However, this does not affect the explanation of the phenomenon; it only locates the disturbing influence in a more improbable region.

With these thoughts paramount it was with considerable anxiety that the developments of the next morning were awaited. It was cloudy, but the clouds were breaking and flying in the face of almost a hurricane. The comet was finally got into the guiding telescope and another exposure began. The flying clouds occasionally permitted the image of the comet to fall on the plate. The little observatory rocked in the wind and the dome threatened every moment to fly away in the direction of San Francisco. A broken half hour's exposure was thus secured, and the resulting picture amply confirmed the disturbance of the previous morning. The tail was broken and seemed to hang in irregular

cloud masses, deflected out of line with the stem of the tail near the head. A portion of the end of the tail was completely detached and was drifting off as an independent comet. This fragment was some four or five degrees from the head and a degree from the nearest part of the tail. Unless this portion dissipates into space it will be an independent comet traveling in quite a different path from the original. Its exact position was right ascension, 12 hours, 20 minutes; north declination, 20 degrees; October 22d, 16 hours 40 minutes, Mount Hamilton mean time. The next morning was cloudy and the full moon now blots out the comet and its phenomena.

The orbit of this object is not yet known, so that it is not possible to say whether it will become a naked-eye comet or not. If it has not yet passed perihelion it will certainly become visible to the naked eye, as it is now but little below that and is getting into a better position for observing. If the comet gets brighter and again presents freaks of the kind described it will be evident that the suggested explanation is at fault and that the comet is possessed of phenomena totally unheard of before. If it does not repeat these changes then the explanation of an encounter with a resisting medium is the only one that will hold, and it will consequently prove of the highest importance to astronomy.

It will be seen, I think, that the theory is at least a good working one, and I trust the reader will see how the subtle photographic plate may reveal to us wonders of a very startling nature where the unaided eye looks upon a blank space only.

It is altogether probable that no other photographs have been made of this comet yet, as it is such an unpromising subject, and that this history of it is recorded only on the Lick observatory photographs.

MOUNT HAMILTON, OCT. 25.

SHOOTING STARS.

How to Observe them and what they Teach us.

W. F. DENNING.

IV. THE OBSERVATION OF METEOR SHOWERS—DIFFERENCES AMONG THEM.

The observation of a rich meteor shower, to be complete, must be undertaken by two observers acting in concert. While one of

them watches the sky continuously and counts the total number of meteors visible and also notes the proportion belonging to the special shower in progress, the other will register the paths, determine the position of the radiant, and record other details not absolutely requiring uninterrupted attention. If one observer only is employed in the work he cannot reckon the number of meteors and register the paths as well, for the latter occasions breaks in the watch which ought to be continuous. He can make allowances, it is true, for the time his attention is withdrawn from the sky, but this is not nearly so satisfactory as counting the actual numbers. The capacity possessed by a single observer is, however, often sufficient to give a good idea as to the character of a shower. When, say, the Perseids are being observed, he should tabulate his results for each evening; he can then, by comparison afterwards, see what changes affect the place of the radiant and the intensity of the shower. As an example of such a table, I give the results of my observations of the Perseids in August last:

Date 1893.	Time of Watch.	Duration.	All meteors seen.	Perseids.	Meteors registered.	Radiant of Perseids.	Weather.
	h m h m	h				° °	
Aug. 5	10 15 to 10 45	1½	13	4	7	39+55	Partly cloudy
8	10 50 to 12 50	2	36	12	14	41+56	Sky clear.
9	11 30 to 14 0	2½	45	20	25	43+57	A few clouds, frequent lightning.
10	10 50 to 11 50	1	21	14	9	45+57	Many clouds.
12	11 30 to 13 0	1½	24	7	11	48+58	Partly cloudy.
13	10 15 to 15 15	3½	43	8	29	48+58	Pretty clear.
14	10 15 to 14 30	4	56	7	36	49+67	Very clear.
15	11 10 to 14 30	3	35	1	22	.....	Very clear.
16	10 15 to 15 15	4½	41	4	29	52+57	Very clear.
5 – 16	10 15 – 15 15	23½	314	77	182	39+55 to 52+57	

Really brilliant showers, like the Andromedes (= Biela's comet) of November 27, 1885, are more fugitive and their great intensity is generally limited to a few hours. In counting the meteors during such a display, the observer should group his observations into short periods of say 5 or 10 minutes and state total number seen during each interval. The time of maximum may then be deduced from the records. The radiant should also be determined, say once during each hour of the shower's progress, for there may be a considerable displacement in the course of a single night. The radiant of the Andromedes is at about 19° + 45½° at 6 P.M.,

but 12 hours later (viz. at about 6 A. M.) it is at 31° + 51° according to theory.

When observations are pursued on ordinary nights solely for the purpose of finding radiant points it is not nearly so important to record the *lengths* of the meteor paths observed as to note the exact *directions* of their flights. The latter feature is in fact all-important, for with accurate materials of this character the radiants become well defined in certain positions. Of course, when observations are undertaken at two or more stations for the express purpose of getting duplicate records of the same meteors with a view to the computation of their real paths in the atmosphere, it then becomes important to note the beginning and end points of the courses with great precision or the observations will exhibit discordances. It is most unfortunate that proper regard is not given to this circumstance by observers generally so that the published accounts of the numerous fireballs which appear unexpectedly might be of real value to those engaged in their investigation. It sometimes happens that a fireball is so generally observed that scores of descriptions of it are printed, but these are usually so rough and unreliable that it is rarely possible to deduce satisfactory results from them. The suddenness of the apparitions and the inexperience of many of the observers doubtless furnish the causes of the errors commonly vitiating the observations.

There is probably no class of phenomena in which more diversity exists than in that comprehended under the title of meteoric astronomy. The number of showers not only appears to be infinite but an endless variety is displayed amongst them; in fact, it would be difficult to find two streams perfectly alike in all respects. The more prominent features in which dissimilarity exists are as follows:

In richness of display.
" periodic time.
" character of radiation.
" duration of activity.
" nature of orbit, etc., etc.

Perhaps it may be as well to say something on these points separately.

In "richness of display" every observer must have quickly recognized the wide distinction that is apparent. There are showers which like the Leonids of 1799, 1833 and 1866 and the Andromedes of 1872 and 1885 are capable of supplying many thousands of meteors in an hour to one observer, while on the

other hand there is a host of feeble systems some of which yield no more than 5 or 6 meteors during watches on several successive nights covering in the aggregate 30 or 40 hours! There are in fact a considerable number of streams of such extreme tenuity that a single observer, though he may watch the sky during an entire night in winter, will only succeed in noting about one meteor from each of them. Yet though so feeble such showers are to be accurately detected and their radiant points correctly assigned by the observer who perseveres in watching for long intervals and who registers the individual tracks with the necessary precision. It might be supposed that such exhausted systems are scarcely worthy of notice and must certainly be very doubtful, but in point of fact their very feebleness makes them interesting and the difficulty of securing them adds a zest to the efforts of the observer. It would be unwise to disregard the weaker streams, for some of the attenuated showers of to-day may form the most brilliant displays of a future time or they may possibly represent the nearly extinct relics of fine showers in past ages. In any case they are worthy of careful observation. Mr. Greg entertained a contrary opinion and his method was to average the positions of a number of radiants lying near together and to consider them as forming one shower, but the writer regards this as a most erroneous practice. We might as well take the mean place of the stars in the Pleiades and catalogue the position as that of a single bright star! The method would simplify matters by reducing the number of objects, but it would not be true to Nature and therefore meets its own condemnation. If the number of showers is so great and the proximity and feebleness of their radiants such that complications arise in dealing with them we must nevertheless face the matter as it stands and endeavour by long and careful study to remove the difficulties. The necessity for generalizing may be felt but it will never do to adopt a sweeping method palpably inconsistent with the direct issues of observation.

With regard to "periodic returns" of showers we find differences similar to that affecting cometary returns. The Leonids furnish us with beautiful displays every 33 years and though the real maximum is confined to a single year yet in the few years preceding and following the maximum fine showers are usually presented. Thus in 1864, 1865, 1867, etc., there occurred conspicuous displays near the great shower of 1866. At the close of the present century we shall doubtless witness some brilliant revivals of this remarkable meteor-system for its parent comet

(I, 1866 Tempel) will revisit us in 1899. The Andromedes of Biela's comet seen in very great abundance on Nov. 27, 1872, and 1885 and more recently on Nov. 23, 1892, furnish an instance of a short period meteor shower and it will probably return in its greatest magnificence in 1898 or 1899. The Andromedes and Leonids constitute the best known and most definite instances of periodical meteor showers. The Lyrids of April, the Perseids of August, the Orionids of October and some other well known systems probably have longer periods which are not yet exactly ascertained. The Perseids and Orionids apparently partake more of a regular annual display without developing periodical outbursts and this appears to be the prevailing feature of the great majority of meteoric systems. They recur every year without special intensity and probably form complete ellipses throughout which the particles are pretty evenly distributed. Undoubtedly a proportion of the known streams have definite peroids of recurring activity, but observation has not yet succeeded in determining many such showers. The writer noticed a rich display of Draconids on Aug. 21-25, 1879 which has not returned since that year, but the inference is that it forms a periodical shower which will reappear at some future time. It is highly probable that condensed meteor groups with periodical maxima, become, in time, distended into complete elliptic streams of annual recurrence. Every particle of such a group would have a slight difference of orbit and period with the effect that after many revolutions the meteors are distributed along the entire orbit.

In our next chapter we hope to refer to differences in the radiation and duration of activity of various systems.

ORBITS OF COMET 1889 V.

H. C. WILSON

This comet was discovered by Mr. W. R. Brooks, then of Phelps, N. Y., July 6, 1889. It was a rather faint telescopic object and would not have attracted very much attention, but for the fact that it was moving in a short ellipse with a period of about 7 years, and that in the year 1886 it must have passed very close to the planet Jupiter and its orbit must then have been very greatly changed. This was pointed out by Mr. S. C. Chandler, in No. 204 of the *Astronomical Journal.* In a later paper (*Astr. Jour.* No. 205) Mr. Chandler gave the results of a rough calcula-

tion of the principal perturbations by Jupiter, that is from Jan. 24 to Sept. 14, 1886, and attempted to trace the course of the comet backward from that time. He found that the encounter with Jupiter in 1886 effected a complete tranformation of the comet's orbit. Instead of the present small seven-year ellipse, it was previously moving in a large one of about 27 years' period, whose aphelion lay outside of Saturn's orbit, and whose perihelion was almost exactly at the present aphelion distance. The direction of the lines of apsides and the nodes were reversed and turned through an angle of about twenty degrees. The plane of the orbit was also tilted about fourteen degrees.

Furthermore, tracing back the course of the comet with the elements of the twenty-seven year ellipse, Mr. Chandler found that the comet must have been very near Jupiter in the year 1779, the very time when the lost comet of Lexell 1770 was in the immediate vicinity of the planet and suffered the notable disturbauce which was supposed to have taken it out of our reach. This coincidence of time and place afforded a strong presumption of the identity of the two comets. Later computations do not confirm this presumption but there remains the very interesting and difficult problem of determining exactly the course of a comet when under the preponderating influence of a great planet.

In recent numbers (302 and 303) of the *Astronomical Journal*, Mr. C. L. Poor has given the results of his investigations in regard to Comet 1889 V. He used as the basis of his work the definitive elements of the comet's orbit computed by Dr. Julius Bauschinger from all the published observations, the latter extending over a period of over eight months. There is still some uncertainty expressed by the factor ν, in these elements, not due to the computations but to the inaccuracies of the observations. Mr. Poor finds that ν is probably within the limits -40 and $+40$. This uncertainty is very slight but enough to affect, to some extent, the character of the calculated approach of the comet to Jupiter. Taking the most probable values of the elements and calculating the perturbations by all of the planets, which could preceptibly influence the comet's motion, back to 1886, Mr. Poor finds that the approach was closer than Mr. Chandler had supposed. The nucleus of the comet passed within the orbit of the first satellite and may have almost grazed the surface of the planet itself.

In calculating the path of the comet when very near to Jupiter Mr. Poor followed the method of transforming the elements of the ellipse around the Sun into those of a hyperbola around Jup-

iter, regarding the Sun as a disturbing body. This transformation was made at the date Oct. 26.5, 1786. After tracing the movement of the comet back around Jupiter for six months the elements were again referred to the Sun as a center at the date March 24.5, 1886, and it was found that the orbit had so greatly changed that the period was then 41.87 years. For several months before that time, however, the perturbations by Jupiter had been large and when these were calculated back to March 14.5, 1884, the elements were found to give a period of 31.38 years, with the perihelion passage July 20, 1886. Mr. Poor thinks that the uncertainty of this period is within two years.

Instead of giving the numerical element of the comet's orbit at the various stages of its transformation* we have attempted to represent them graphically by means of the diagrams, Figures 1 and 2. In Fig. 1, the four elliptic orbits are shown together with the orbits of Earth, Jupiter, Saturn and Uranus. The four ellipses of the comet's path all meet near that point of Jupiter's orbit which is opposite the vernal equinox. For two of them this is the most distant part of the orbit (aphelion), for the other two it is the nearest part (perihelion). One can see at a glance what a tremendous change in the path of the comet occurred between March and October, 1886.

Interpreting the elements with the aid of the figure they tell us that the comet previous to 1884 was moving in a large ellipse the nearest point of which to the Sun lay very close to Jupiter's path, and the farthest point about half way between the orbits of Saturn and Uranus. The plane of the orbit was inclined at an angle of about 7° to ecliptic and the orbit crossed the latter from south to north in longitude 186°, very near the path of Jupiter. This orbit is represented in Fig. 1 by the line marked "Orbit of Comet 1889 V in March, 1884." The comet was describing this path at the rate of a revolution in about 31.38 years. Had it not been influenced by Jupiter it would have gone around this orbit again and again and never have been seen from the Earth. As it happened to come to perihelion at the same time that Jupiter was in that vicinity, it was drawn at first very gradually, then more rapidly, from the large, smooth curve of Figure 1 into the larger dotted curve, then into the smaller dotted curve, and finally and gradually into the slightly larger smooth curve. This last curve, "Orbit of Comet 1889 V in 1889," it will continue to follow for several revolutions of seven years' period

* These elements are given in *Astronomy and Astro-Physics*, Nov. 1893, p. 795.

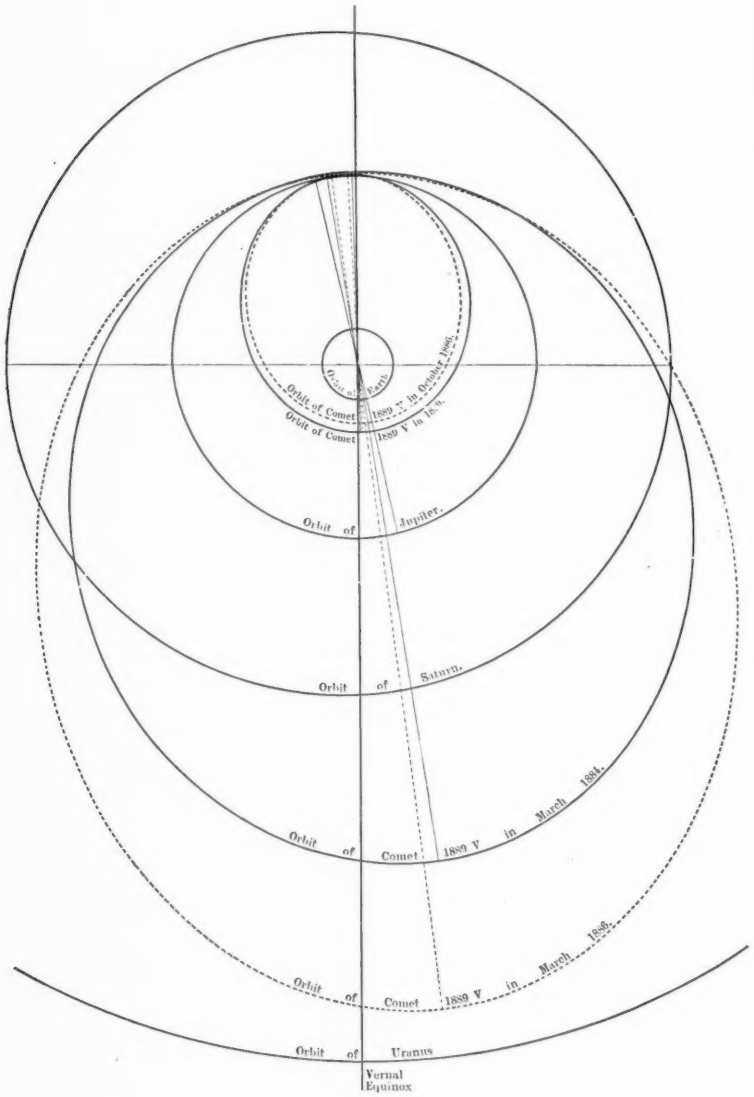

Orbit of Earth.
Orbit of Comet 1889 V in October 1885.
Orbit of Comet 1889 V in 1886.
Orbit of Jupiter.
Orbit of Saturn.
Orbit of Comet 1889 V in March 1884.
Orbit of Comet 1889 V in March 1888.
Orbit of Uranus
Vernal Equinox

FIG. 1.—THE ORBITS OF COMET 1889 V BEFORE AND AFTER ITS APPROACH TO JUPITER IN 1886.

with only slight modifications by the planets. In 1921 another close approach to Jupiter will occur, which, though not so close as the one in 1886, will considerably change the orbit, probably making it larger and possibly removing the comet from the reach of our telescopes for a long period.

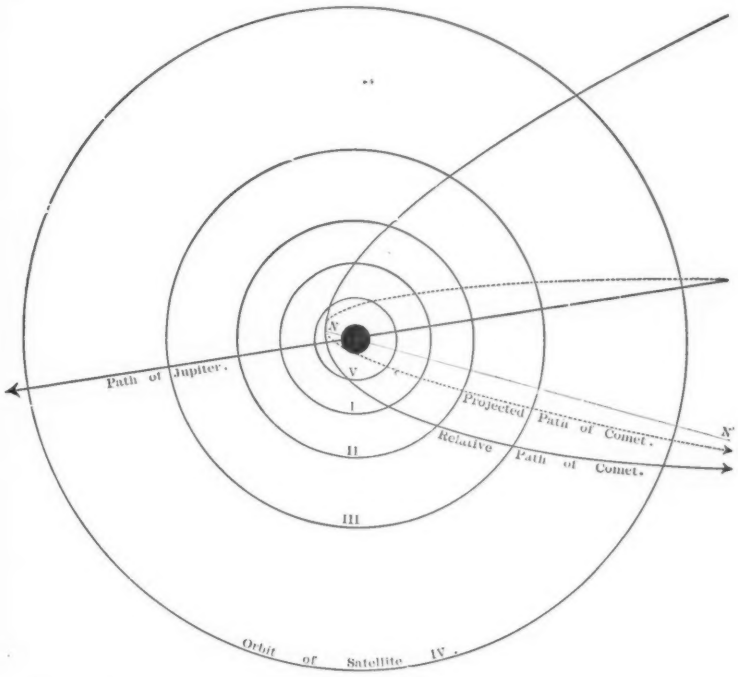


FIG. 2.—THE PATH OF COMET 1889 V THROUGH JUPITER'S SATELLITE SYSTEM JULY 18 TO 21, 1886.

Fig. 2 represents a portion of the hyperbolic orbit of the comet relative to Jupiter while it was passing through the system of the satellites, and is especially interesting in showing how very close the comet came to the planet and the satellites. The scale is nearly 4000 times that of Fig. 1. The time of nearest approach to Jupiter was found to be July 20, when the distance was only 2.31 radii of the planet, with the uncertainty expressed by r in the formula

$$q = 2.31 + 0.033r$$

"That is, the comet not only passed through the system of Jup-

iter's satellites, but it actually passed within the orbit of the first satellite whose mean distance is 5.93 radii of the planet. Taking the extreme limits of ν we are safe in saying that the comet passed the center of Jupiter at a distance not greater than 3.63 and not less than 1.00 radii of the planet. In other words the center of the comet may have grazed the surface of Jupiter, and it certainly approached that surface to within a distance of 2.63 radii of the planet, or only 112,300 miles. Even this latter is a very small quantity.

"For the most probable hypothesis, that of $\nu = 0$, the comet was 2.65 days within the system of Jupiter's satellites, and during this time it made nearly a complete curcuit about the planet, passing over an arc of 313° of longitude. The comet entered the Jovian system in longitude 118° on July 18.77, passed the planet July 20.10, at a distance of only 2.28 radii, and July 21.43 left the system in longitude 71°. During this time it must have collided with one or more of the satellites."

The last two paragraphs are quoted from Mr. Poor's paper. In Fig. 2 the circles represent the orbits of Jupiter's satellites and the relative path of the comet is almost a hyperbola and was drawn from the mean of the parabolic elements given for Oct. 26.5 and March 24.5, 1886. It is necessary to understand that the path of the comet is a plane inclined at an angle of about 70° to the plane of the satellite orbits, so that the comet did not pass horozontally across them, but came up through from below. The line NN′ represents the line of the nodes or intersection of the planes of the comet's path and the ecliptic.

The reader must understand, too, that this is only the path relative to Jupiter and that the latter was at the same time moving rapidly along its orbit, so that while the comet, after July 20, was apparently moving backward with reference to Jupiter, with reference to the Sun it was moving forward and changing from the larger dotted orbit to the smaller one in Fig. 1.

It will be noticed that the path of the comet passes very close to that of the new satellite (V) of Jupiter and suggestions have already reached us from different sources, that possibly this comet had something to do with the origin of the new satellite, that in fact the satellite is a captured fragment of the comet. We cannot see how this could be, with the comet passing through the system just as it did, and supposing the capture to have occurred, cannot acconnt for its brilliancy, since the whole comet was invisible long before it reached the distance of Jupiter.

If the period of 31.38 years is correct this comet cannot be identical with Lexell's comet of 1770 unless marked perturbations occurred between 1886 and 1779 when the latter was in the vicinity of Jupiter and had its orbit greatly changed, for the interval of 107 years is not a multiple of 31.38 years or any number very near that. Mr. Poor finds that there was no very near approach of the comet to Saturn in that interval but that possibly a very close approach to Jupiter occurred in 1791. This, however, would be fatal to identity with Lexell's comet, for it would require the comet between 1779 and 1791 to have a period equal to that of Jupiter, that is an identical orbit.

SUGGESTIONS TO AMATEURS.

LEWIS SWIFT.

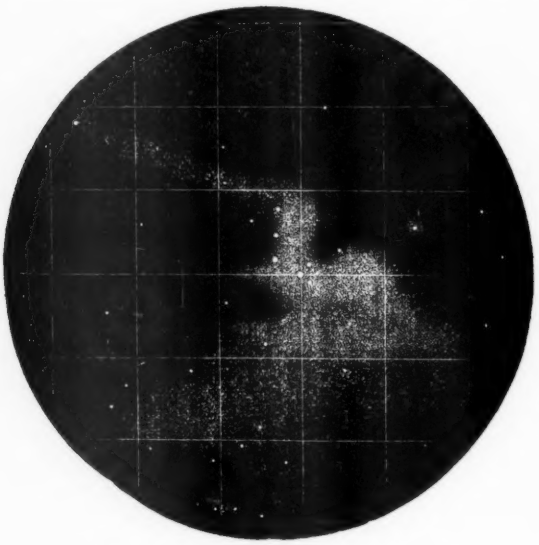
The Great Nebula in Orion.

The largest and one of the brightest and, in many respects, the most remarkable nebula known is that found in the constellation of Orion, right ascension, about $5^h\ 30^m$; declination, south 5°. It is impossible to name its exact position, as is true of all the large, irregular nebulæ unless they possess a conspicuous central point for reference, which the Orion nebula has not. As examined with different telescopes under varied atmospheric conditions, its entire contour is changed with each, so that each individual observer, according to the size of the telescopes employed and the excellence of the seeing, locates the selected center. With my 16-inch glass, using a superior and large periscopic eyepiece giving a low power and a large field, I have several times traced the outlines of this nebula far beyond its generally assigned limits. Professor Wm. H. Pickering has given it an extension nearly equal to that of the constellation itself, and including several neighboring nebulæ heretofore supposed to have no connection with it.

When the constellation is veiwed with the naked eye, the first objects to attract attention are the three conspicuous stars of equal magnitude in a line about one and a half degrees apart called, variously, the three stars, the yard and ell, and the belt of Orion, but which Job designates as the Bands of Orion, "Canst thou bind the cluster of the Pleiades or loose the bands of Orion?" Job xxxviii: 31, Revised Ed.

Neither the date of discovery of this nebula nor the name of its discoverer is certainly known. It has been generally ascribed to

Huygens, in 1656, but eighteen years previous to its mention by Huygens, Cysat, of Lucerne, in describing the appearance of the head of the comet of 1618, compares it to the nebula in Orion. This allusion, while nullifying the claim of Huygens, does not, by any means, prove Cysat its discoverer, indeed it would rather argue its having been known previously, but Dr. Dreyer in his "New General Catalogue of Nebulæ" accords Cysat this honor.



NEBULA OF ORION (*Messier 1771*).

When viewed with small telescopes these hazy objects appeared only as small, whitish spots, but, looked at with larger glasses, some were resolved into stars, and so the inference was that all nebulæ were clusters and resolvable did we possess telescopes of adequate power. As a result of this erroneous theory, some astronomers, finding a star or two depicted on a nebula, have assumed and announced that the objects were no longer to be regarded as nebulæ but as clusters. Sir William Herschel claimed to have resolved into stars the great Whirlpool nebula in Canes and the great nebula in Andromeda, and others have asserted that the Orion nebula and the ring nebula in Lyra, also, had been found to be clusters of stars, while the truth is that the last two are pronounced gaseous by the spectroscope. It is only lately, with our mammoth telescopes, that a single star has been seen either on or within the ring of the last named.

The distance of the nebulæ from the earth has been a much discussed question, and it has been contended that they may not be so far off as the nearest stars, but as the distance of both is unknown, any assertion regarding this is futile. The Orion nebula has many stars, some bright, but mostly faint, scattered over its surface, but, judging from their telescopic apearance, they lie between us and the nebula.

Here we are confronted with some startling facts. All stars are suns, and all, even under the highest powers of the largest telescopes, appear as points of light. A point, having no extension, cannot, of course, be magnified. The nearest star to us, Alpha Centauri, is, presumably, as large as our Sun, and yet, so far away is it that though nearly a million and a half times the size of our Earth it is reduced to a mathematical point. Now, superimposed on the Orion nebula are stars as large as Alpha Centauri on which no telescope can raise a disc, while the nebula itself, probably somewhat spherical in form and probably as far distant as the stars, presents a disc covering at least one-hundred square degrees. What little things even the gigantic suns must be in comparison with this which is, however, only one of the eight thousand nebulæ which our telescopes reveal!

No lateral motion has ever been detected in any nebula. It is only because the stars are points that their proper motion, as it is termed, is measurable. The telescope only takes cognizance of this kind of motion, while the spectroscope is employed altogether for the detection of motion in the line of sight, either toward or from the observer. By the tele-spectroscope at the Lick Observatory Professor Keeler ascertained that the Orion nebula is moving from us or we from it at the rate of about ten miles per second. The probability is that this motion is nearly all, if not wholly due to that of the solar system toward the apex of the Sun's way, in the neighborhood of the constellation of Hercules.

Several nebulæ are scattered over the constellation of Orion which even in large telescopes, appear to be independent; but which with long photographic exposure (too long for the brighter portion of the great nebula) the negative shows to be connected with the principal nebula, whose proportions are thus expanded to an extent undreamed of a few years ago.

My library is largely packed for shipment and I cannot now recall wherein I recently read the statement that the nebulæ close to ζ Orionis, the lowest of the three stars of the Belt, were lately discovered by photography. Unless a new one is alluded to, which I

doubt, this is all a mistake. Close to this star, so near, in fact, that to see them the star has to be placed out of the field of the telesocope, are four nebulæ with which I have been familar for more than thirty years. They or it, as he supposed, were discovered by Sir Wm. Herschel on New Year's Day, 1786, and registered as number 28 of his class V (large) and described as having "diffused nebulosity." Auwers' description says "divided in three or four large patches including a dark space. Cannot take up less than one half a degree, but I suppose it to be much more extensive." Dreyer, in New General Catalogue, where its number is 2024, after calling it a wonderful object says of it, "irregularly resolvable, very, very large black space inclosed." Of these descriptions Auwers' appears to me to be the only correct one. As to its resolvability I have very many doubts. Formerly, before the sky was illuminated by the electric lights, I saw them (for there are certainly four) as well with my 4½-inch as latterly with my 16-inch telescope. To see it well about one-fourth of the field should be hidden by a bit of smoked mica. This, if the eyepiece be properly rotated, will bring them into the center of the field with the star obscured.

My reasons for calling the attention of amateurs to this object are threefold:

1. To correct the statement that it was discovered by photography.

2. To suggest that it is visible in small telescopes by getting the star out of the field.

3. Because of the astonishing fact that, though 5° distant, it has been proved to be connected with the great nebula itself.

Sir William Herschel supposed he had discovered a very large, very faint nebula surrounding Epsilon Orionis (the Belt's middle star). For this I have sought many times with both telescopes, but always in vain, having never been able to detect anything more than the faint glow which surrounds every bright star. Auwers is inclined to believe in its existence, and Dr. Dreyer states that he has seen it at the Armagh Observatory as an exceedingly diffused nebula of the Merope type. This assertion that the star is eccentrically situated in the nebula, argues strongly against the glow hypothesis. There is a black opening or bay running into the nebula at the end of which small telescopes reveal four faint stars which, though on three sides close to the nebula appear to be not involved with it. The group is named the trapezium of Orion. Large telescopes show two of the stars to be double. Much speculation has been had as to the

cause of the exceeding blackness of the opening. The same phenomenon may be observed in hundreds of places in the Milky Way, though most of these are small. A few, however, are large, one notably so, viz.: the coal-sack of Sagittarius which nearly fills the field of my 16-inch glass, and within which but three stars are found and one of those very difficult to perceive. Two opinions are advanced to account for the excessive blackness: Barnard, who has photographed it, revealing on the negative plate thousands of stars too faint to be detected by any telescope, thinks, as did Herschel, that it is simply an opening, while others ascribe it to a black nebula existing between us and it. Having given some attention to these "coal-sacks," especially to this one and the many scattered over the constellation of Cygnus, I have come to the conclusion that this darkness is not real, and that, in truth, they are no blacker than other portions of the sky, but that their apparent blackness is due wholly to the effect of contrast with the brightness of their surroundings. As to the final history of such a gigantic volume of self-luminous matter, the largest object on which the eye of man has ever rested, or the source of its self-luminosity it would be idle to speculate.

VARIABLE STARS. II.

J. A. PARKHURST.

In my first paper in the November POPULAR ASTRONOMY I gave the classification of variables with regard to their length of period. Before passing to the methods of observation the color of variables should be mentioned.

For some unknown reason the variables, if not white, are yellow, or orange, or red, and as a rule the longer the period, the more intense is the redness. Dr. Chandler has expressed the redness in a decimal scale in which 0 corresponds to white and 10 to the most intense red known in stars. Measured on this scale the stars with periods of from 150 to 500 days show a steady increase in redness. This will be seen from the following table in which the first column gives the limits of the periods, the second, the number of stars, and the third the average redness.

Period.	No.	Redness.
150 to 200	9	2.3
200 " 250	13	2.6
250 " 300	24	3.4
300 " 350	25	3.8
350 " 400	23	4.6
400 " 450	11	6.1
450 " 500	4	8.1

Designation of Variables.

The earliest mode of naming variables was by capital letters, beginning with R (suggesting the redness generally accompanying variability) prefixed to the name of the constellation. Thus R Cassiopeiæ stands for the first variable discovered in Cassiopeia. When the final letters of the alphabet are exhausted, they are doubled. Thus we have RR, RS, and RT Cygni, etc. But so much confusion has arisen from different letters being assigned to the same star by different authorities that Dr. Chandler has devised a more complete method by which that difficulty is avoided. The star's Right Ascension for the year 1900 is reduced to seconds of time and one tenth of the number is taken. For instance the Right Ascension of U Geminorum for 1900 is $7^h\ 49^m\ 10^s$, which equals $28{,}150^s$, so its number is 2815. When a star is suspected to be variable the number is placed in parenthesis; when the variability is proved the parenthesis is removed and the letter assigned. Thus (1805) Orionis is a star in Orion whose variability is suspected by Boss, and 2815 U Geminorum is the full designation of a star proved to be variable.

Methods of Observation.

The best method of observing a variable consists in comparing it with a star a little brighter and one a little fainter. In this way small changes of light can be readily detected, and with practice quite accurately estimated. Since only the relative light of two stars is concerned the accuracy of the observation will be but slightly affected by altitude, haze, moonlight or twilight, while the absolute brightness might be greatly changed by such varying conditions.

There are several ways of estimating the interval in brightness between the variable and the comparison star, but all things considered the method known as Argelander's seems the best. It is as follows: Select a star slightly brighter than the variable, calling it *a*, also one slightly fainter, call it *b*. If the variable seems equal to *a* the observation can be recorded *av* or *va*, (the variable being designated by *v*).

If *a* is a little brighter than the variable but to such a slight degree that you could not imagine a star between them in brightness and distinguishable from each, the observation is recorded *a* 1 *v*, the brighter star always written first. This interval is called a step or grade, and practically is the smallest interval in brightness which the observer can detect, If the interval is such

that a star can be imagined between *a* and *v* differing a step from each, the record is *a* 2 *v*, if the interval is a little greater, it will be *a* 3 *v*. Intervals exceeding three or four steps are uncertain, so that comparison stars should be selected within a few steps of the brightness of the variable if possible.

In the same way compare the variable with a fainter star *b*, and make the record *v* 1 *b*, *v* 2 *b*, as the case may be, always writing the brighter star first. The value of a step will of course be different with different observers, but this is immaterial. With practice it will become quite a constant quantity with the same aperture and magnifying power but will decrease if an eye-piece of higher power is used. The value of a step with experienced observers is generally about one-tenth of a magnitude, for the beginner it is apt to be somewhat larger.

Pickering suggests another method of estimating the interval between the variable and the comparison stars. "Select two stars for comparison, one *a* slightly brighter than the star to be measured, the other *b*, slightly fainter. Estimate the brightness of *v* in tenths of the interval from *a* to *b*. Thus if *v* is midway between *a* and *b* the interval will be five-tenths, and we may write *a* 5 *b*. If *v* is nearly as bright as *a* we may have *a* 1 *b* or *a* 2 *b*. If *v* is not much brighter than *b* we may have *a* 8 *b* or *a* 9 *b*."

In comparing these two methods probably nine out of ten would at first prefer the latter, but after a little experience would find Argelander's better. The great superiority of the step method lies in the fact that the observations may be reduced and the star's light curve drawn, its maximum and minimum determined, without any previous knowledge of the magnitudes of the comparison stars. The observations themselves furnish a value for the brightness of the comparison stars by means of which a "light scale" can be formed and the variable's light curve drawn. If the observer already has well determined values of the magnitude of the comparison stars, this advantage would not count, but in general he will not have, so the method by which such values become unnecessary will be a great boon.

The method of reducing the observations, drawing the light curve and finding from it the maximum and minimum, will form the subject of the next paper. In the mean time some suggestions in regard to details of the observations will be in order.

The observer will need a list of comparison stars ranging in brightness from a little above the variable at its maximum to a little below it at its minimum. This list need not all be selected

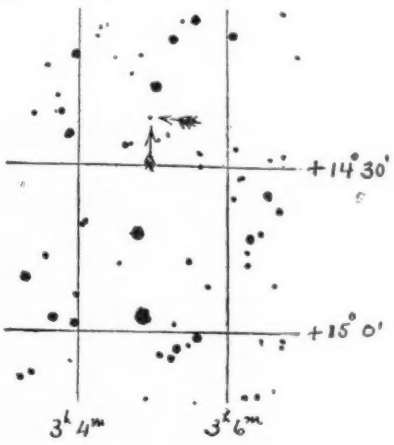
at once, indeed the exact brightness of the variable at maximum or minimum may not be known, but stars may be added to it from time to time as they are needed. The stars should be, if possible, not more than five or six steps, say half a magnitude, apart, and are most convenient if they are so placed that each can be seen in the same field with variable with the lowest power eyepiece. This ideal selection of comparison stars is not always possible, one is often compelled to choose between stars of convenient distance but large intervals in brightness, and good intervals but inconvenient distances. Avoid choosing a comparison star close to a brighter star as the estimate of the fainter star will thus become difficult and uncertain. Do not choose a double star if the components are visible with the power used. Make a sketch of the relative positions of the variable and the comparison stars chosen, as well as any other stars near. Letter the comparison stars with small letters, beginning with either the brightest or the faintest star used. In this way stars will always be designated in the record by letters and intervals by numbers, and thus confusion will be avoided. Low altitude, haze, twilight or moonlight injure the quality of the observations to some extent, since they affect white and red stars differently. Red stars gain in relative brightness when viewed under those conditions, and as a rule the variable is red and the comparison stars white. If observations are made at such times the record should show it, so that less weight may be given to the observation and any resulting anomalies accounted for. Note the time of the observation, if of an Algol star the hour and minute, if a long period variable the hour will suffice. It is best to bring the star observed to the center of the field, or if the two stars to be compared are not far apart, place them at equal distances from the center. A star looks brighter near the edge of the field than at the center. It is better to look carefully at each star separately, glancing back and forth several times, rather than to try to see two stars at once. The lowest power eyepiece is the most convenient to use, since it gives the widest field and the best choice of comparison stars. As far as possible use the same eyepiece for all the observations of a given star. Do not use too large an aperture with bright stars. When the variable is of the sixth to eight magnitude two inches aperture is better than three or four. The eye is not sensitive to small differences in bright stars.

The light used in consulting charts and making records should be no brighter than necessary. The eye should be screened at all times from its direct rays, and the comparisons themselves

should be made in darkness. The ideal light is a one-half or one candle power incandescent lamp. This may be run by two chromic acid or storage cells, or by four Leclanché or dry cells. The writer uses a one-half candle power Edison lamp run by three storage cells, the latter charged by ten gravity cells. Three storage cells are used because the battery is in the cellar three hundred feet from the Observatory. The gravity cells are recharged only once in three weeks, so that the expense is small and the convenience great.

The accompanying table and charts will aid the amateur in identifying specimen variables.

No.	Star	1900.0 Right Ascension h	m	s	Declination °	′	Redness	Mag. Max.	Min.	Period d
116	β Cassiopeiæ	0	19	15	+ 63	35.5		>1	?	
1113	U Arietis	3	5	30	+ 14	24		7.8	< 11	330?
5955	R Draconis	16	32	23	+ 66	57.8	2.0	7.6	12.5	245.6
7609	T Cephei	21	8	13	+ 68	5.0	6.3	5.8	9.7	383.3



The chart for U Arietis is taken from *Astronomy and Astro-Physics* for October, 1892. The position of the variable is shown by the arrows. The stars shown are from the 8.7 to 11.5 magnitudes. Only one maximum of this star has been observed visually, 1893, Jan. 1. Its period is not definitely known, and observations are needed. The star is 5° south of the 4th magnitude star δ Arietis.

The other three charts are drawn from the *Astronomische Gesellschaft* Zone Catalogues. All the stars to about the 9th magnitude are shown besides some fainter stars near the variable, which is indicated by a dot in a circle, the conventional symbol for a variable. It will be noticed that the charts are drawn inverted, as the stars appear in an astronomical eyepiece, with north at the bottom, west to the left.

B Cassiopeiæ is Tycho Brahe's New Star of 1572. It can be readily located from the star marked κ (4.3 magnitude), the northernmost, and faintest, of the four stars forming the seat of the "chair." In answer to D. F.'s query in the October POPULAR

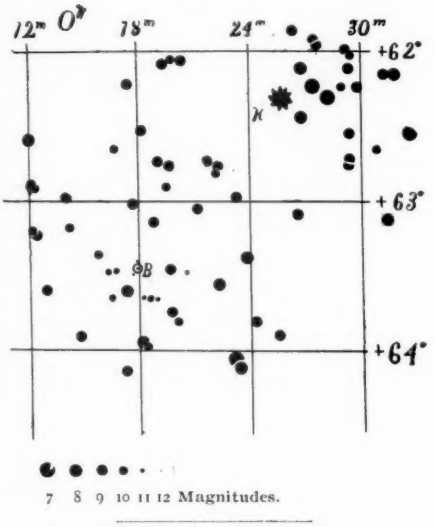
ASTRONOMY page 96, I, would say that if by 30′ Right Ascension he means 30^m, the star he observed was 12^m east of B, if he means 30′ his star was 16^m too far west. There is no star visible exactly in the position given by Tycho, but the two faint stars shown near it should be watched. They were of the 11th or 12th magnitude Nov. 13, 1893, and require a four-inch telescope to see them well. (See October number, p. 91.)

R Draconis is 5° north and ½° east of the third magnitude star η Draconis. T Cephei is 2° south and 1° west of β Cephei (3rd magnitude). All three stars, U Arietis, R Draconis and T Cephei will be near the 9th magnitude in December. Observation should be made and reported.

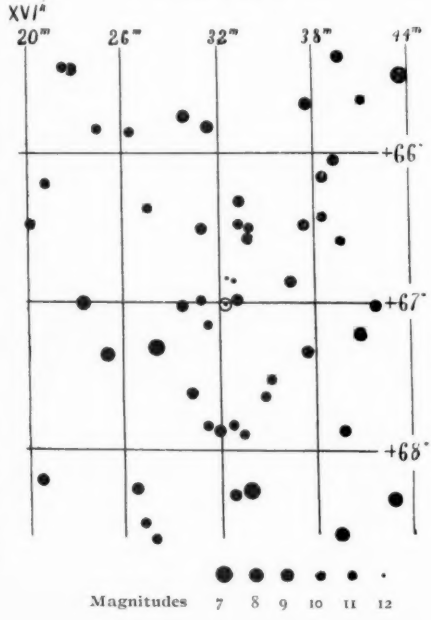
If the observer has neither Heis', Proctor's nor Klein's atlas, Young's Uranography (Ginn & Co., 35 cents), will be found very convenient for locating variables.

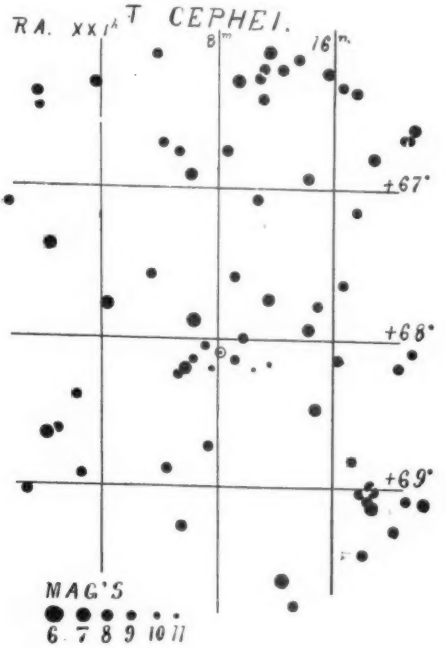
Don't record your observations on slips of paper. Draw sketches and make records in a note book. Date the ob-

B CASSIOPELÆ.



R DRACONIS.





servations and record the quality of the seeing. Feel free to ask questions.

In the next paper the list of variables will be extended and methods of reduction given.

MARENGO OBSERVATORY,
1893, Nov. 1.

DANIEL KIRKWOOD.

WM. W. PAYNE.

Daniel Kirkwood, the subject of this brief sketch, who resides at Riverside, California, and who is now in feeble health, was born in Harford County, Maryland, September 27, 1814. His parents, John and Agnes (Hope) Kirkwood, were both natives of Maryland, of Scotch-Irish descent, his ancestry having filled positions in the Presbyterian church for nearly two centuries. His father's farm was not very productive, and a resi-

dence on it afforded indifferent prospects for acquiring an education. His early efforts with that end in view are remembered as he informs us with mingled emotions of pain and pleasure. The boy in early life planned perhaps sometimes not wisely for the future.

The morning in May, 1822, is well remembered when his sister and himself, with their dinners safely wrapped in a small basket, started to a school kept by a Mr. Roderic Slayman, at Mount Horeb two miles east of his father's place. His mother's admonitions are not forgotten—her cautions in regard to his intimate associates, careful attention to Mr. Slayman's instructions, etc. His reading book (which has been lost for two-thirds of a century) was "*The Economy of Human Life.*" It seemed to have been based on Chinese maxims, the philosophy of Confucius, etc. The New Testament was taken later. Life was then new. Dreams of the future had not yet stirred the young blood. If distant glimpses of the years to come were sometimes caught they were temporary. Several years later the mysteries of numbers were encountered. New questions arose. At nineteen the thought of teaching occurred. A small country school in Hopewell, York County, Penn., was taken. Among his scholars a young man, who subsequently became a successful minister, presented himself. Mr. Kirkwood relates this incident in regard to this young man: "'Do you teach Algebra?" He asked me. I answered, 'No. I have heard it spoken of. The letters of the alphabet are used instead of figures, but I have not learned how to use them.' A neighbor of his had bought an old copy of Bonnycastle's Algebra at a book-auction, and disposed of it to the student. He brought the book with him, and together we solved its mysteries. The next spring, 1834, I found my way to the York County Academy, of which the Rev. Stephen Boyer, an alumnus of Jefferson College, was Principal. He at once assigned me to the Elements of Euclid, and started me on a course of mathematical study. My residence was with Professor Boyer till 1843, his faithfulness as a teacher and as a friend was long appreciated."

In speaking of early years Mr. Kirkwood says the instructors of his youth have been remembered with gratitude. Roderic Slayman, John Sharp, Henry Fulton, Dr. Joshua W. Bennett, John B. Henderson and Rev. Stephen Boyer, A. M., inspired his ambition. To the last named in particular, from early manhood, he felt under strong obligations. Entering his family about 1834, he continued a member till elected Principal of the

PLATE IX.

DANIEL KIRKWOOD.

POPULAR ASTRONOMY, No 4.

Lancaster High School, in November, 1843. While in Lancaster, Mr. Kirkwood was united in marriage with Miss Sarah A. McNair. The ceremony was performed by Rev. Alfred Hamilton, Pastor of Fagg's Manor Presbyterian church, Chester County, Pennsylvania, December 25, 1845.

Mr. Kirkwood received the honorary degree of *Master of Arts* from *Washington College*, Pennsylvania, in 1848; and that of *Doctor of Laws* from the *University of Pennsylvania* in 1852. He is the well known author of *Meteoric Astronomy*, *Comets and Meteors* and *The Asteroids*, published by Lippincott & Co., Philadelphia, 1867—1888. He has been a professor in Delaware College, in the University of Indiana and in Washington and Jefferson College. At the opening of the Leland Stanford, Jr., University, in California, he was invited to accept the appointment of Non Resident Lecturer on Astronomy.

He is now in the eightieth year of his age and still has a lively interest in the recent advancement of science and writes for publication as his strength will allow.

THE SPECTROSCOPE AND SOME OF ITS APPLICATIONS.

JAMES E. KEELER.

III. *Practical Details Relating to the Adjustment and Use of the Instrument.*

A spectroscope like that described in my first article can be made without much difficulty by the amateur possessed of a fair amount of mechanical skill, with the exception of the prism, which may reasonably be assumed to be beyond his powers. Small spy-glasses with objectives from ¾-inch to 1-inch aperture can be bought for less than two dollars apiece, and their objectives are sometimes surprisingly good; at any rate they are good enough for the low power of seven or eight which is all that is required for the spectroscope. One of these spy-glasses will do for the observing telescope, although the terrestrial eyepiece could be advantageously replaced by an astronomical one of about an inch focus, and the other can be transformed into a collimator by removing the eyepiece and fitting a slit into its place. The telescope and prism should be mounted on a small wooden or metal table, in a manner which will readily occur to anyone with a mechanical turn of mind.

The slit requires some careful work, as any little irregularity in its jaws will show in the spectrum. The reason of this is evident; in observing the solar spectrum the slit is very narrow, say not more than a thousanth of an inch wide, and hence a variation of a fraction of this width will make a perceptible difference in the amount of light admitted. The jaws must be filed as straight as possible, and then ground together with fine emery until they fit exactly. In fine instruments the jaws are made of very hard steel or other hard substance to avoid danger of nicking. When they are mounted, one jaw may be held with a single screw so that it can readily be made parallel to the other, or movable one. If the slide of the latter is not carefully fitted, the slit will be liable to open faster at one end than at the other, a fault which is very annoying in observation.

I have referred to the prism as offering special difficulties of construction, and it may be worth while to consider what they are. We have seen that in order to give a distinct image of the slit, *i.e.* a sharp spectral line, the surfaces of the prism must be flat and the glass homogeneous, for otherwise the parallel rays which fall on the prism will not be parallel on leaving it. Now these conditions are not easily met, with the accuracy which is requisite. In ordinary language we speak of a table-top or a window-pane as being flat, but in optics we are held to a much stricter interpretation of "flatness." As all human workmanship is imperfect, it is a matter of great interest to determine *how nearly flat* the surface of a prism must be in order to give good definition, or more generally, how great a deviation is permissible in any optical surface from the true mathematical form which it should have. The answer to this important question is given by the wave-theory of light, and it has been shown that no considerable part of a wave-front of light should be more than a quarter of a wave-length from its proper place. A reflecting surface should therefore be true to within one-eighth of a wave-length, (the light has both to pass into and out of any depression), while a refracting surface of ordinary glass may be in error by half a wave-length without producing a greater error than a quarter wave-length in the refracted wave, the exact amount depending upon the refractive power of the glass. The small effect of oblique incidence of the light is not considered.

These results find immediate application in many practical problems. We may consider, for instance, (to make a slight digression), the highly interesting case of the silvered-glass reflector and inquire whether irregularities in the silver film can injuriously

affect the image. Dr. Draper found that the silver film on his mirrors was $\frac{1}{2000}$ of an inch thick, which is about a quarter of a wave-length of light. As variations in the thickness could hardly be supposed to exceed half this amount, and are probably very much smaller, we conclude that the mirror is optically of exactly the same figure as if it were unsilvered.

Returning to the prism, we see that its surfaces should be true to within about half a wave-length, or $\frac{1}{4000}$ of an inch; as there are two surfaces which might possibly act together in producing errors, perhaps we should say to within half this amount.

Exacting as these requirements seem to be, they are easily met, and even greatly exceeded, by modern opticians. I have in my possession a small flat piece of glass by Mr. Brashear, the surface of which has no error exceeding one-twentieth of a wave-length, or about the millionth part of an inch.* Probably this degree of accuracy has never been surpassed. Holding the glass between the fingers instantly destroys the perfection of its figure.

It is possible for the errors in one surface of the prism to correct those in the other, although as the tendency in polishing is to make the surface convex, such a compensation is not likely to occur. Nearly all the older prisms I have examined have convex faces, and sometimes exhibit large and curious irregularities of figure. Such prisms may be serviceable, although they will not give the best results. The accuracy which I have described is equivalent to perfection, and something short of perfection can be tolerated.

If the glass is not homogeneous the parallelism of the rays will likewise be destroyed, and the Fraunhofer lines cannot be brought sharply into focus when the prism is used in the spectroscope. If the surfaces are found to be flat, a prolariscope will generally show strains in the glass, due to imperfect annealing. Only the best optical glass is suitable for fine prisms.

In adjusting the spectroscope, the refracting edge of the prism must be placed perpendicular to the plane containing the collimator and the telescope, *i.e*, vertical, if the prism table is horizontal. Sufficient accuracy can be insured by rotating the prism slightly about the position of minimum deviation, and observing whether the spectrum remains central in the field of the observing telescope as it travels to and fro. If it rises or falls, one of the prism angles requires elevation. A small obstacle

* Such minute errors as this cannot of course be directly measured, or even detected by the common method of testing the reflection from the surface with a telescope. Delicate interference methods must be used.

placed on the center of the slit will produce a strong "dust-line" in the spectrum, which may be of assistance in making this adjustment.

The slit must, as we have seen, be placed in the principal focus of the collimator lens, in order that the rays falling on the prism may be parallel. The usual method of effecting this adjustment is as follows: the telescope is removed from the spectroscope, and focused on a distant object, the eyepiece having first been focused on the cross-wires, if there are any. Then the telescope is placed so as to look directly into the collimator, and the slit is focused until it is distinctly seen; the slit is then (optically) at the same distance as the object on which the focus of the telescope was adjusted.

There is another method of making this adjustment which is more accurate than the preceding one, and which does not require the telescope to be removed from the apparatus. The prism must be movable. To adjust the collimator and telescope by this method the observer should proceed as follows: set the slit by guess, and focus the telescope on some particular line in the spectrum when the prism is in minimum deviation, first focusing the eyepiece on the cross-wires, if there are any, when the same line is in the center of the field. Now rotate the prism slightly, in such a direction that the light falls more obliquely on its first face, so as to displace the line perhaps half the breadth of the field, and move the telescope until the line is in the center of the field again. The line will generally appear much blurred. Focus the telescope until it is seen distinctly, without disturbing the collimator, and then rotate the prism back past the position of minimum deviation, and beyond it, until the same line is brought to the center of the field again, the rest of the apparatus remaining unchanged. The line will probably be blurred. Focus the collimator this time until the line is sharp, and repeat the operation, always focusing the telescope in the first position of the prism and the collimator in the second, until no further change is required. This method is so accurate that the difference of focus of the lenses for different parts of the spectrum can easily be measured.

Since in the first position of the prism the dispersion is less and in the second position greater than in the position of minimum deviation (see the experiment of our first article), we may lay down the following rule for this method of adjustment, in which it is not necessary to remember the angles of incidence on the prism faces; *focus the telescope when the dispersion is diminished,*

and the collimator when it is increased. As the spectrum is always under the eye of the observer, there is no danger of mistaking the position of the prism when this rule is used. If the prism is used in the wrong position every time, the telescopes will get farther and farther out of focus, instead of continually approximating toward it.

The *rationale* of the process is briefly outlined below. Parallel rays falling on a prism remain parallel after passing through it, in all positions of the prism, but rays that are inclined to each other will have their inclination changed, unless the prism is in the position of minimum deviation. Suppose that in setting the slit by guess, it is placed inside the principal focus; then the rays coming from the collimator will *diverge*, as if they came from an object (say) 25 feet away, and the telescope, when focused on the slit, or on the lines in the spectrum with the prism set to minimum deviation, will be adjusted for an object at this distance. When the prism is turned to position 1, the divergence of the rays passing through it is diminished, as if they came from an object (say) 100 feet distant, and if the telescope is now focused on the lines it will be set for an object at this distance, and will be more nearly right than it was before. On turning the prism to minimum deviation, and focusing the slit, the optical distance of the slit will be increased to 100 feet; or by focusing when the prism is in position 2, something still greater, so that by a series of approximations, the optical distance of the slit is made infinite, and the rays emerging from the collimator are parallel. The process described above in general terms is readily followed mathematically.

In observing the Fraunhofer lines it will be noticed that the focus of the telescope has to be changed considerably in passing from one end of the spectrum to the other, although the lenses of both telescope and collimator are nominally achromatic. This change is inconvenient and objectionable, particularly if distances between lines are to be measured, as any disturbance of the adjustments between the settings is liable to introduce errors; but it cannot be helped. With simple lenses, (which it has been suggested might be used in a spectroscope, since each line is formed of monochromatic rays), the difficulty would be very much increased, so that only a very small part of the spectrum could be seen distinctly at one time. For general purposes therefore the lenses should be achromatic, and in a fine instrument the eyepiece should be achromatic also. Even then, as the eye itself is not perfectly achromatic, the cross-wires cannot always be sharply seen without changing the adjustment of the eyepiece.

In the spectroscope which I have described, the Fraunhofer lines are not perfectly straight, but slightly curved, the convex side being turned toward the red end of the spectrum. Rays from the top of the slit are converged to form the lower end of its image and therefore pass obliquely through the prism. Only the rays which come from the centre of the slit and go to the center of the image pass through the prism in a horizontal direction, and as the angle between the sides of the prism is greater in an oblique than in a horizontal section, the oblique rays are slightly more deviated. Formulæ have been obtained for the curvature of the lines, but they are not of much practical use, and indeed very few cases arise in which the curvature has to be considered. In measuring the positions of lines the middle or least deviated points are bisected by the cross-wires.

The spectroscope assumes such a variety of forms that it is impossible in the space at our disposal to describe the different kinds in use. Only a few of them however are really effective, and we may consider the most important of these. In no form are the materials more advantageously applied than in the simple spectroscope which has already been described.

If another prism is added to this spectroscope the deviation and dispersion will be doubled, and the power may be still further increased by adding more prisms. Each prism must be in the position of minimum deviation, and the angle between the faces of adjacent prisms is the same throughout the whole train. As the dispersion is now so great that only a small part of the spectrum can be seen at once in the field of the telescope, the telescope must be moved to bring in any other part, and this involves the readjustment of all the prisms in the train—a very troublesome matter. To avoid the labor of adjustment the prisms are generally linked together in such a manner that each angle changes by the same amount. Assuming that the prisms are all alike, a little consideration will show that the following conditions must be fulfilled: The bases of all the prisms must be tangent to a circle, the diameter of which is variable, depending upon the part of the spectrum observed, and the center of the circle must travel on a line perpendicular to the collimator axis. One of the simplest ways of meeting these conditions is to connect the telescope and collimator by a broad metal spring, to which the bases of the prisms are fastened, and which by its elasticity keeps a circular form when bent, but there are other and probably better ways. Some old spectroscopes with prism trains are very defective in regard to these requirements. The

prisms are adjustable in angle by linked tail-pieces, but not in distance from the center. At the ends of the spectrum most of the light is therefore lost. The prism train, ingeniously modified in many different ways, was formerly much used for solar observations where high dispersion is required, but it has now been almost superseded by the diffraction grating.

The compound prism now much used consists of a highly dispersive flint glass prism with large refracting angle (90° or more), enclosed between two thin crown glass prisms placed in reversed positions. The crown glass prisms partially counteract the effect of the dense one. They are cemented to the faces of the flint glass with Canada balsam, as otherwise the light would not emerge from the heavy prism, but would be totally reflected at its inner face.

The direct vision prism used in pocket spectroscopes may be regarded as an extreme case of the same construction, the crown glass wedges being enlarged until they equal the dense prism in refractive power for some middle part of the spectrum, while they do not entirely counteract its dispersion. Sometimes five prisms are put together in the same way, two of them being of flint and three of crown glass. This form of prism is not very efficient, as the same dispersion could be obtained with a much smaller single prism of the ordinary shape, but when the direct view is preferred they are convenient. The pocket spectroscope usually has no collimator,—only a single lens which is focused on the slit, and the rays are not parallel when they pass through the prism. It is a peculiarity of the direct-vision prism, resulting from the symmetry of its construction, that the divergence or convergence of a pencil of rays is not altered by it, and hence it will give distinct vision even when the rays passing through it are not parallel.* In this respect it resembles the single prism used in the position of minimum deviation.

(*To be Continued*).

To drop a pea at the end of every mile of a voyage on a limitless ocean to the nearest fixed star would require a fleet of ten thousand ships of 600 tons burthen, all starting with a full cargo of peas. SIR JOHN HERSCHEL.

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* The pencil of rays remains *homocentric* after refraction; all the rays produced backward meet in a single point, and are therefore converged by the eye to a single point on the retina. A familiar instance of the confusion resulting from nonhomocentric rays is the difficulty of seeing objects in an aquarium, especially when they are viewed obliquely.

THE YERKES' TELESCOPE.

W. W. PAYNE.

We present elsewhere a fine picture of the Yerkes' telescope, prepared especially for this publication. In the October number of *Astronomy and Astro-Physics*, we gave a frontispiece plate of the same telescope, which is excellent in most particulars, but in some not quite satisfactory. The plate herewith given shows the details of the mounting at the top of the pier more favorable and about as faithfully as can be done by an engraving of the kind. The background, however, does not show in as lively contrast, nor is it as definite in detail as the other picture evidently because most of the objects composing it are farther removed from the telescope. In this picture the telescope is the prominent object as it manifestly ought to be.

Some idea of the size and weight of the different parts of this great telescope may be gained from a statement of the leading facts pertaining to them, as given by Mr. W. R. Warner, of Messrs. Warner & Swasey, of Cleveland, Ohio, in a paper read before the Congress of Astronomy and Astro-Physics at Chicago. The three great telescopes of this country are, the new 26-inch equatorial of the Naval Observatory at Washington, the 36-inch Lick telescope at Mt. Hamilton and the 40-inch Yerkes instrument of Chicago University. In these great telescopes special attention must be given to the manner in which the tubes are made which carry the lenses. The two essential points are, lightness and ridigity, the former for ease of motion, the latter to make the flecture of the tubes as small as possible. The material best calculated to give these two qualities is sheet steel. The form of the tube has much to do with its ridigity, a slight increase in diameter at the center serving to stiffen it, and, on this account thinner material can be used. The following is Mr. Warner's description of the principal features of the mounting:

"The tube for the 40-inch Yerkes telescope is 42 inches in diameter at the objective end, 52 inches at the center, and 38 inches at the eye-end. The sheet steel forming the tube varies from 7.32 inches in thickness at the center to 1.8 inches at the ends. The total weight of the tube is six tons.

The declination axis carrying the tube is of forged steel, 12 inches in diameter and 12 feet long, its weight being 1½ tons. This runs in segmental babbitt bearings in the declination sleeve, which weighs 4 tons. The polar axis carrying the whole system

is of hard forged steel, 15 inches in diameter at the upper bearing and 12 inches at the lower bearing, and weighs 3½ tons.

Just above its upper bearing it carries the main driving gear, weighing 1 ton and having 330 teeth, by which the movement of the driving clock is communicated to the polar axis.

The great weight of the bearings of these axes is almost wholly relieved, and the resistance changed from slidng to rolling friction by means of three bracelets or live rings of steel rolls. One of these encircles the declination axis near the tube, and one is placed above each bearing on the polar axis These anti-friction live rings run in steel yokes, and are pressed against the axes by means of adjustable spring levers.

The live ring of rolls which is on the declination axis near the tube is the centre of gravity of the system comprising the tube and the declination axis with their attachments, this one series of rolls serving to take the weight off both bearings of the declination axis, and so nearly eliminating friction that less than one pound of direct pressure on the tube is required for each ton of weight moved. This live ring is composed of 16 inch rolls, 5 inches long, and 3 inches in diameter, and carries a total weight of 8 tons.

The live ring at the upper end of the polar axis is composed of 16 rolls, 6 inches long, and 4 inches in diameter. This sustains a weight of nearly 20 tons. The end-thrust of all this great weight, due to the angle at which the axis is placed, is taken on a double series of 40 one-inch hardened steel balls.

The methods of balancing the movable parts of the Yerkes telescope have been a special study, with results which seem all that can be desired.

The heaviest accessory to be used with the telescope is the solar spectroscope. With this in position, the tube is accurately balanced. Weights are then placed on the extension of the declination sleeve until the whole system is in balance. When the solar spectroscope is to be removed sufficient supplementary weights are placed at the side of the eye-end of the tube, so the balance is not disturbed.

The equatorial head and its bearings supporting the polar axis and the entire movable part of the telescope, are cast in one piece, its base conforming to the rectangular shape of the column.

The column is 11 ft. × 5 ft. at the base, tapering to 10 ft. × 5 ft. at the head. It is cast in five sections, having internal flanges for securely bolting it together. In the upper section is placed the driving clock. A spiral staircase at the south side of the column

gives easy access to the driving clock, and also to the balcony surrounding the head.

The Driving Clock is governed by a double conical pendulum, mounted isochronously, and making sixty revolutions per minute.

A driving weight, considerably in excess of the amount required to drive the telescope, is used with this clock, the surplus of power being taken by a friction ring placed just above the pendulum. The arms of the pendulum are so arranged that in operation they always take their natural and theoretical positions, not being swerved therefrom by the action of the power on the friction ring above mentioned. When the clock is unclamped from the polar axis, all the power required to move the telescope is instantly transferred to the friction ring, and the pendulum maintains its theoretical position and normal rate. An electric motor is provided for automatically winding the clock.

When the 40-inch objective is completed a detailed statement about it of interest to the general reader will be given. The lenses are now in the hands of Mr. Alvan G. Clark, of Cambridgeport, Mass., who is working on the local corrections necessary to the high excellence which is always found in the Clark lenses.

VISUALIZING THE EARTH'S ANNUAL MOTION.

ELIZA A. BOWEN.

My design in writing this article is to show how the Earth's annual motion can be visualized.

We can fix with exactness the position which the Earth has at any time relative to the Sun, by supposing a straight line passing through the centers of the two bodies, and then finding the two points through which it would extend among the stars on the celestial sphere. Such a line, passing through the Sun, the center of that sphere, would be a diameter of it, and the two points must be 180° apart. The method of finding such points with instruments is easy to understand, but it is in books, and to explain it here would make this article too long. Those who have made the measurements tell us that during the latter part of December, such a line through the centers of the Earth and Sun, would reach a point in the constellation Sagittarius on the side of the Sun; and on the side of the Earth, a point in Gemini.

The observer should first go out at sunset. He can imagine the line spoken of as touching the celestial horizon behind the center

of the Sun, then passing through the Sun and Earth, and touching the celestial horizon in the East. Sagittarius, of course, is obscured by the Sun, which appears to be on the celestial sphere. This appearance, however, is due to perspective. We know, because the Earth has been between Saggittarius and the Sun, that the constellation is at a very great distance from the Sun, and the observer must get this fact firmly fixed in his mind.

The observer sees that the constellations of the zodiac form a ring round the heavens, and that the Earth's path, or orbit, lies within this ring. But those persons who have discovered all the points on the sphere which, during a year, would be successively reached by the lines through the centres of Earth and Sun, tell us that they lie on the circumference of a great circle extending along the middle of the zodiac. The area within the circumference of a circle is a plane, therefore the Earth's center moves round the Sun in one plane. This plane is called the ecliptic, and the circle is called the circle of the ecliptic.

At any sunset, the Earth's path for the previous six months always lies in the space above us, a great semi-circle (nearly) with one end beyond the opposite side of the Sun, and the other coming down to the centre of the Earth. The band, or ring, of zodiacal constellations shows the direction of this path.

The part of the plane of the ecliptic which appears to lie within the celestial sphere is surrounded by the circle of the ecliptic. The line of this circle extends along the middle of the band or ring of the zodiacal constellations. The axis of the celestial sphere is a line passing through the poles of the heavens and through the centre of the plane of the ecliptic. You cannot see the axis, but you can identify its northern extremity by the pole star.

Numeration of the Asteroids discovered in 1893.—Numbers have recently been assigned to twenty-one of the asteroids discovered by photography this year. Seven others designated 1893 C, D, M, O, U, X, and Y, were not sufficiently observed to permit of determining their elliptic orbits. They therefore receive no numbers. The asteroid 1893 Q has been found to be identical with (104) Klymene, Z with (175) Andromache, AF with (158) Koronis, and AG with (107) Camilla.

The numbers assigned are as follows:

1893 A	Jan. 17	Charlois	354	1893 S	Mar. 17	Charlois	363
B	12	Wolf	352	T	19	"	364
E	20	Charlois	356	V	21	"	365
F	16	Wolf	353	W	21	"	366
G	21	Charlois	355	AA	May 20	"	367
J	Feb. 11	"	357	AB	20	"	368
K	Mar. 8	"	358	AC	July 14	"	370
L	9	"	359	AD	16	"	371
N	11	"	360	AE	5	Borrelly	369
P	11	"	361	AH	Aug. 19	Charlois	372
R	17	"	362				

THE FACE OF THE SKY.

CHARLOTTE R. WILLARD.

Six o'clock December twentieth will afford a convenient opportunity for making thought definite in regard to sidereal time. We say it is noon when the sun is on our meridian, just so it is sidereal noon when the "First of Aries" is on the meridian; this will occur at six o'clock on the day named. Noticing carefully what stars are crossing the meridian at this time the brighter ones are, one in the base of the Great Dipper (γ Ursæ Majoris), the most western star in Cassiopeia (β) and one of the western stars in the Square of Pegasus (α Andromedæ). It will be noticed that the line of these stars passes through the pole star, and is perpendicular to the horizon; it will be of interest to observe these one, two and three hours later noticing the angle which their line then makes with the perpendicular drawn through the pole to the horizon; practice will enable one to estimate this angle with a fair degree of accuracy and so to determine approximate sidereal time. Sidereal noon comes nearly four minutes earlier on each succeeding night. The distance from β Cassiopeiæ to α Andromedæ is 30°, following their line for nearly 30° farther south, we locate the intersection of the celestial equator and the ecliptic (*i. e.* The First of Aries). The equator may be traced from this point to the east passing close to the star δ Orionis and to the west passing 9° below Altair (α Aquilæ). The ecliptic passes eastward between the Hyades and Pleiades, and to the west a few degrees above the second magnitude star δ Capricorni.

The most beautiful of all constellations and the most brilliant of fixed stars will be noticeable objects in the western sky during the coming month. The star Sirius will rise at about seven o'clock on the first of January, preceding it by two hours is the very striking constellation Orion, sometimes described as a kite. The central part of this constellation is marked by the belt of Orion, a line of three second magnitude stars (δ, ε and ζ). Two first magnitude stars are located symmetrically north and south of this line—the northern Betelgeuse (α Orionis) and the southern one Rigel (β Orionis). It is interesting to notice that β is now brighter than α. About 8° preceding α is γ, a second magnitude star, these two mark the shoulders of Orion, and between them is a group of three fainter stars forming the head. From the belt depend three stars known as the sword. Rigel is one of the many double stars of this constellation; its components are of first and ninth magnitude, they have been distinctly seen with a 4½-inch telescope and just detected with a 1½-inch. δ is a double with magnitudes 2 and 7. σ, a faint star below ζ, is triple, the magnitudes being 4, 8 and 7; it has been seen as triple with a 4⅞-inch glass. Rigel and ε are said to be moving directly away from us at rates respectively of 39 and 35 English miles a second, and yet so immense is their distance that they seem to shine with undiminished light from night to night. θ, the middle star of the sword, is really two stars θ and θ'; θ' is of peculiar interest. "On very slight telescopic persuasion it allows itself to be seen as quadruple;" these four stars respectively 5, 6, 7 and 8 in magnitude form the well known trapezium of the great nebula of Orion. Two and a half centuries of observations cannot detect the slightest shifting of their positions, and seem to declare their distances enormous even on the scale of stellar distances. Two other much fainter stars have been seen in the group by aid of glasses of 3 and 4 inch aperture. "The whole frame work of the great nebulous structure in the Sword of Orion seems to rest upon this stellar group." This is one of the many cases where multiple

stars seem to bear close relation to nebulæ; such cases suggest the question as to whether the formation of a double in the nebulous field may not be the first step toward the formation of crowded clusters like the Pleiades. Space will not admit of a description of the Great Nebula—it is appearing greater and greater as improved instruments push its boundaries farther from the centre.

Sirius is by far the brightest of all fixed stars, for this reason astronomers have from earliest time paid much attention to problems concerning it. The story of their slow yet marvelous progress in its study is most fascinating. It was found to have a measurable parallax, its distance was calculated, its motion, though apparently slight, was found to be disturbed, and astronomers said "Sirius has a companion which no man has seen." This companion was studied and its motions confidently described for twenty years before any man succeeded in seeing it. Faith *was* the evidence of things not seen. It was first seen in 1862 by an 18-inch glass. Sirius is believed to emit forty times as much light as our Sun. The companion is strangely lacking in brilliancy.

PLANET NOTES FOR JANUARY.

H. C. WILSON.

Mercury having been at greatest western elongation Dec. 14 will in January be too close to the Sun for observation. He will be at superior conjunction Jan. 29 at $6^h\ 36^m$ A. M.

Venus which has been such a brilliant object in the early evening sky during the past month will be still more brilliant during the first part of January. This planet will attain its maximum brilliancy on Jan. 10 when the light will be 218 as compared with 145 on December 1. The position of Venus is becoming a little more favorable for observation in northern latitudes, as the planet moves northward in declination. Venus and the crescent Moon will be in conjunction on the morning of Jan. 10 and the two will form a pretty pair on that evening and the preceding.

Mars will be morning planet during January, visible in the southeast after five o'clock. The low altitude will prevent good observations in our latitude, but south of the equator something may be done in the study of the surface markings of the planet. Mars and the waning Moon will be in conjunction on the morning of Jan. 3, the latter passing 4° south of the former.

Jupiter will be in excellent position for observation during the first half of the night in January. The planet will be stationary among the stars of Taurus on Jan. 15, after which it will move slowly eastward.

Saturn is getting into better position for observation in the morning but the majority of observers will prefer to wait two or three months until the planet is visible in the evening. Saturn will be at quadrature, 90° west from the Sun, Jan. 14. Saturn is in the constellation Virgo a little northeast of Spica and is moving very slowly eastward. The Moon will be 4° south of Saturn at noon Jan. 27.

Uranus is in the constellation Libra a little way east of the star α. It is not yet in very good condition for observation in our latitude.

Neptune having passed opposition in December will be in excellent position for observation in January. It will move very slowly westward during the month, the position January 1 being a little more than ⅓ of the distance on a straight line from ι to ε Tauri. There is no star of equal brightness within a radius of 1°.

Planet Tables for January.

[The times given are local time for Northfield. To obtain Standard Times for Places in approximately the same latitude, add the difference between Standard and Local Time if west of the Standard Meridian or subtract if east].

Date. 1894.	R. A. h m	Decl. ° ′	Rises. h m	Transits. h m	Sets. h m
		MERCURY.			
Jan. 5	18 06.0	− 24 00	6 44 A. M.	11 04.9 A. M.	3 25 P. M.
15	19 14.0	− 23 53	7 12 "	11 33.3 "	3 54 "
25	20 24.1	− 21 26	7 31 "	12 04.0 P. M.	4 37 "
		VENUS.			
Jan. 5	22 01.3	− 11 39	9 43 A. M.	2 59.5 P. M.	8 16 P. M.
15	22 18.6	− 8 06	9 06 "	2 37.6 "	8 09 "
25	22 23.6	− 5 16	8 21 "	2 03.2 "	7 46 "
		MARS.			
Jan. 5	16 04.4	− 20 33	4 26 A. M.	9 03.6 A. M.	1 41 P. M.
15	16 33.2	− 21 49	4 22 "	8 53.0 "	1 24 "
25	17 02.6	− 22 47	4 16 "	8 43.0 "	1 10 "
		JUPITER.			
Jan. 5	3 17.6	+ 17 16	1 00 P. M.	8 15.0 P. M.	3 30 A. M
15	3 17.0	+ 17 16	12 20 "	7 35.0 "	2 50 "
25	3 17.7	+ 17 22	11 41 A. M.	6 56.3 "	2 12 "
		SATURN.			
Jan. 5	13 34.3	− 7 12	12 59 A. M.	6 33.8 A. M.	12 09 P. M.
15	13 35.8	− 7 19	12 22 "	5 56.1 "	11 30 A. M.
25	13 36.8	− 7 21	11 43 P. M.	5 17.7 "	10 52 "
		URANUS.			
Jan. 5	14 48.6	− 15 49	2 49 A. M.	7 48.1 A. M.	12 47 P M.
15	14 49.9	− 15 55	2 12 "	7 10.1 "	12 09 "
25	14 51.0	− 15 59	1 33 "	6 31.8 "	11 30 A. M
		NEPTUNE.			
Jan. 5	4 39.8	+ 20 36	2 04 P. M.	9 36.9 P. M.	5 09 A. M.
15	4 39.0	+ 20 35	1 24 "	8 56.8 "	4 29 "
25	4 38.3	+ 20 34	12 44 "	8 16.8 "	3 59 "
		THE SUN.			
Jan. 5	19 07.1	− 22 34	7 38 A. M.	12 05.8 P. M.	4 34 P. M.
15	19 50.5	− 21 02	7 35 "	12 09.8 "	4 45 "
25	20 32.8	− 18 50	7 27 "	12 12.6 "	4 58 "

Phases and Aspects of the Moon.

		Central Time. d h m
Apogee	Jan.	5 6 00 A. M.
New Moon	"	6 9 07 P. M.
First Quarter	"	14 6 09 P. M.
Perigee	"	20 9 12 A. M.
Full Moon	"	21 9 12 A. M.
Last Quarter	"	28 10 51 A. M.

Approximate Central Standard Times when the Great Red Spot will cross the Central Meridian of Jupiter.

	h m		h m		h m
Jan. 2	12 40 A. M.	12	6 48 P. M.	22	5 06 P. M.
2	8 31 P. M.	14	12 36 A. M.	23	10 53 "
3	4 23 "	14	8 27 P. M.	24	6 45 "
4	10 10 "	15	5 18 "	26	12 31 A. M.
5	6 01 "	16	10 06 "	26	8 24 P. M.
6	11 48 "	17	5 57 "	27	4 15 "
7	7 40 "	18	11 44 "	28	10 02 "
9	1 27 A. M.	19	7 36 "	29	5 54 "
9	9 18 P. M.	21	1 22 A. M.	30	11 41 "
10	5 10 "	21	9 14 P. M.	31	7 33 "
11	10 57 "				

Jupiter's Satellites for January.

Phases of the Eclipses of the Satellites for an Inverting Telescope.

I. r

III. d r

II. d r

IV. No Eclipse.

Configuration at 9h for an Inverting Telescope.

Day.	West	East.
1	2 1 ○	3 4
2	2 ○	3 1 4
3	3 1 ○	4 2
4	3 ○ 2 1	
5	4 2 3 1 ○	
6	4 1 ○ 3	2 ●
7	4 ○ 1 2 3	
8	4 1 2 ○	3
9	4 2 ○	3 1
10	4 3 1 ○	2
11	3 4 ○	2 1
12	3 2 1 4 ○	
13	○ 1 3 ○	4 2 ●
14	○	2 3 4 1 ●
15	1 2 ○	3 4
16	2 ○	1 3 4
17	1 3 ○	2 4
18	3 ○	1 2 4
19	3 2 1 ○	4
20	3 2 ○ 1 4	
21	4 ○	3 2 1 ●
22	4 1 2 ○	3
23	4 2 ○	1 3
24	4 1 3 ○	2
25	3 ○	1 2
26	4 3 2 1 ○	
27	4 3 2 ○	1
28	4 1 ○	3 2
29	○ 2 1 ○ 4	3
30	2 ○	1 4 3
31	○ 3 1 ○	2 4

In the preceding diagram the light discs in the middle vertical row represent the planet Jupiter. The numbers give the relative positions of the satellites respectively and the periods near them their direction of motion. The black discs on the right with the numbers show which satellites are occulted or eclipsed; the light discs on the left, which are in transit on the face of Jupiter. The letters *r* and *d* at the top of the page mean reappearance and disappearance respectively.

Phenomena of Jupiter's Satellites.

Central Time.

		h	m							h	m			
Jan.	5	12	07	A. M.	II	Tr. In.	Jan.	15	6	27	P. M.	I	Sh. Eg.
		12	18	"	I	Tr. In.			8	33	"	II	Sh. Eg.
		1	22	"	I	Sh. In.		17	5	22	P. M.	III	Sh. In.
		2	13	"	II	Sh. In.			7	15	"	III	Sh. Eg.
		2	28	"	II	Tr. Eg.		20	10	26	"	I	Tr. In.
		2	30	"	I	Tr. Eg.			11	30	"	II	Oc. Dis.
		3	34	"	I	Sh. Eg.			11	41	"	I	Sh. In.
		9	32	P. M.	I	Oc. Dis.		21	12	39	A. M.	I	Tr. Eg.
	6	12	47	A. M.	I	Ec. Re.			7	42	P. M.	I	Oc. Dis.
		6	38	P. M.	II	Oc. Dis.			11	08	"	I	Ec. Re.
		6	46	"	I	Tr. In.		22	4	54	"	I	Tr. In.
		6	48	"	III	Oc. Dis.			6	10	"	I	Sh. In.
		7	51	"	I	Sh. In.			6	21	"	II	Tr. In.
		8	37	"	III	Oc. Re.			7	07	"	I	Tr. Eg.
		9	58	"	I	Tr. Eg.			8	22	"	I	Sh. Eg.
		10	03	"	I	Sh. Eg.			8	43	"	II	Tr. Eg.
		11	05	"	II	Ec. Re.			8	50	"	II	Sh. In.
		11	18	"	III	Ec. Dis.			11	12	"	II	Sh. Eg.
	7	12	57	A. M.	III	Ec. Re.		23	5	37	"	I	Ec. Re.
		4	00	P. M.	I	Oc. Dis.		24	5	35	"	II	Ec. Re.
		7	16	"	I	Ec. Re.			6	09	"	III	Tr. Eg.
	8	4	32	"	I	Sh. Eg.			9	24	"	III	Sh. In.
		5	54	"	II	Sh. Eg.			11	18	"	III	Sh. Eg.
	12	11	23	"	I	Oc. Dis.		28	12	19	A. M.	I	Tr. In..
	13	2	43	A. M.	I	Ec. Re.			1	36	"	I	Sh. In.
		8	35	P. M.	I	Tr. In.			2	00	"	Ii	Oc. Dis.
		9	03	"	II	Oc. Dis.			9	35	P. M.	I	Oc. Dis.
		9	46	"	I	Sh. In.		29	1	04	A. M.	I	Ec. Re.
		10	27	"	III	Oc. Dis.			6	47	P. M.	I	Tr. In.
		10	48	"	I	Tr. Eg.			8	05	"	I	Sh. In.
		11	25	"	II	Oc. Re.			8	54	"	II	Tr. In.
		11	26	"	II	Ec. Dis.			8	59	"	I	Tr. Eg.
		11	58	"	I	Sh. Eg.			10	18	"	I	Sh. Eg.
	14	12	19	A. M.	III	Oc. Re.			11	17	"	II	Tr. Eg.
		1	41	"	II	Ec. Re.			11	29	"	II	Sh. In.
		5	50	P. M.	I	Oc. Dis.		30	1	50	A. M.	II	Sh. Eg.
		9	12	"	I	Ec. Re.			4	04	P. M.	I	Oc. Dis.
	15	3	03	"	I	Tr. In.			7	33	"	I	Ec. Re.
		3	49	"	II	Tr. In.		31	5	39	"	II	Oc. Re.
		4	14	"	I	Sh. In.			5	55	"	II	Ec. Dis.
		5	15	"	I	Tr. Eg.			8	03	"	III	Tr. In.
		6	11	"	II	Tr. Eg.			9	11	"	II	Ec. Re.
		6	11	"	II	Sh. In.			10	03	"	III	Tr. Eg.

Occultations Visible at Washington.

Date 1894.		Star's Name.	Magnitude.	IMMERSION Washington M. T.		Angle f'm N pt.	EMERSION Washington M. T.		Angle f'm N pt.	Duration.	
				h	m	°	h	m	°	h	m
Jan.	11	χ Aquarii.....5½		6	52	89	7	48	198	0	56
	18	136 Tauri.....5		16	16	105	17	05	266	0	49
	19	W. VI, 1656.....8		17	08	140	17	48	247	0	40
	20	e Geminorum...6		4	49	110	5	38	254	0	49
	20	ω^1 Cancri.....6		12	19	83	13	25	319	1	06
	20	ω^2 Cancri.....6		12	54	129	14	04	273	1	10

Elongations of the Satellites of Saturn.

(The western elongations will be found approximately half way between the eastern and other positions may be easily interpolated.)

MIMAS.

		h		
Jan.	2	5.7	A. M.	W
	3	4.3	"	W
	4	2.9	"	W
	9	7.3	"	E
	10	6.0	"	E
	11	4.6	"	E
	12	3.2	"	E
	13	1.8	"	E
	17	7.6	"	W
	18	6.2	"	W
	19	4.9	"	W
	20	3.5	"	W
	21	2.1	"	W
	25	7.9	"	E
	26	6.5	"	E
	27	5.1	"	E
	28	3.7	"	E
	29	2.3	"	E

ENCELADUS.

Jan.	2	2.2	A. M.	E
	3	11.9	"	E
	4	7.9	P. M.	E
	6	4.8	A. M.	E
	7	1.7	P. M.	E
	8	10.6	"	E
	10	7.5	A. M.	E
	11	4.3	P. M.	E
	13	1.2	A. M.	E
	14	10.1	"	E
	15	7.0	P. M.	E
	17	3.9	A. M.	E
	18	12.7	P. M.	E
	19	9.6	P. M.	E

ENCELADUS Cont.

		h		
Jan.	21	6.5	A. M.	E
	22	3.4	P. M.	E
	24	12.3	A. M.	E
	25	9.1	"	E
	26	6.0	P. M.	E
	28	2.9	A. M.	E
	29	11.8	"	E
	30	8.7	P. M.	E
Feb.	1	5.5	A. M.	E

TETHYS.

Jan.	2	11.7	P. M.	E
	4	9.0	"	E
	6	6.3	"	E
	8	3.6	"	E
	10	12.9	"	E
	12	10.2	A. M.	E
	14	7.5	"	E
	16	4.8	"	E
	18	2.1	"	E
	19	11.4	P. M.	E
	21	8.7	"	E
	23	6.0	"	E
	25	3.3	"	E
	27	12.6	"	E
	29	9.9	A. M.	E
	31	7.2	"	E

DIONE.

Jan.	2	12.7	P. M.	E
	5	6.3	A. M.	E
	7	midn.		E
	10	5.7	A. M.	E
	13	11.4	A. M.	E

DIONE Cont.

		h		
Jan.	16	5.0	"	E
	18	10.7	P. M.	E
	21	4.4	"	E
	24	10.1	A. M.	E
	27	3.7	"	E
	29	9.4	P. M.	E

RHEA.

Jan.	2	5.0	P. M.	E
	7	5.4	A. M.	E
	11	5.9	P. M.	E
	16	6.1	A. M.	E
	20	6.5	P. M.	E
	25	6.9	A. M.	E
	29	7.3	P. M.	E

TITAN

Jan.	3	8.2	P. M.	S
	7	3.5	"	E
	11	1.2	"	S
	15	5.0	"	W
	19	7 1	"	S
	23	2.3	"	E
	27	noon		I
	31	3.6	"	W

HYPERION.

Jan.	6	3 9	A. M.	E
	12	12.1	P. M.	I
	17	8.5	"	W
	22	6.3	A. M.	S
	27	10.1	"	E

IAPETUS.

Jan.	20	4.3	P. M.	E
Feb.	7	10.5	"	I

Minima of the Variable Stars of the Algol Type.

[Given to the nearest hour in Central Standard Time.]

U CEPHEI.

R. A.....$0^h\ 52^m\ 32^s$
Decl.....$+81°\ 17'$
Period.....$2d\ 11^h\ 50^m$

Jan.	5	1 A. M.
	9	midn.
	14	"
	19	"
	24	11 P. M.
	29	11 "

ALGOL.

R. A.....$3^h\ 1^m\ 1^s$
Decl.....$+42°\ 32'$
Period.....$2d\ 20^h\ 49^m$

Jan.	2	2 A. M.
	4	11 P. M.
	7	8 "
	10	5 "
	22	4 A. M.
	25	1 "
	27	10 P. M.
	30	7 "

R. CANIS MAJORIS.

R. A.....$7^h\ 14^m\ 30^s$
Decl.....$-16°\ 11'$
Period.....$1d\ 3^h\ 16^m$

Jan.	1	9 P. M.
	2	midn.
	4	3 A. M.
	9	7 P. M.
	10	11 "
	12	2 A. M.
	13	5 "
	17	6 P. M.
	18	10 "
	20	1 A. M.
	21	4 "
	26	8 P. M.
Jan.	27	midn.
	29	3 A. M.
	30	6 "

S CANCRI.

R. A.....$8^h\ 37^m\ 39^s$
Decl.....$+19°\ 26'$
Period.....$9d\ 11^h\ 38^m$

Jan.	7	4 P. M.
	17	3 A. M.
	26	3 P. M.

S ANTLIÆ.

R. A.....$9^h\ 27^m\ 30^s$
Decl.....$-28°\ 09'$
Period.....$0d\ 7^h\ 27^m$

Jan.	1	2 A. M.
	2	1 "
	2	midn.
	3	"
	4	11 P. M.
	5	10 "
	6	10 "
	7	9 "
	8	5 A. M.
		8 P. M.

S. ANTLIÆ CONT.

Jan.	9	4 A. M.
		8 P. M.
	10	4 A. M.
		7 P. M.
	11	3 A. M.
	12	2 "
	13	2 "
	14	1 "
	14	midn.
	15	"
	16	11 P. M.
	17	10 "
	18	10 P. M.
	19	5 A. M.
		9 P. M.
	20	5 A. M.
		8 P. M.

S. ANTILÆ CONT.

Jan.	21	4 A. M.
		8 P. M.
	22	3 A. M.
	23	3 "
	24	2 "
	25	1 "
	26	1 "
	26	midn.
	27	11 P. M.
	28	11 "
	29	10 "
	30	9 "
	31	9 "

δ LIBRÆ.

R. A..... $14^h\ 55^m\ 06^s$
Decl..... $-\ 8°\ 05'$
Period..... $2d\ 07^h\ 51^m$

Jan.	2	1 A. M.
	9	1 "
	15	midn.
	22	"
	29	11 P. M.

U. CORONÆ.

R. A ..... $15^h\ 13^m\ 43^s$
Decl..... $+\ 32°\ 03'$
Period..... $3d\ 10^h\ 51^m$

Jan.	11	7 A. M.
	18	4 "
	24	2 "
	31	midn.

COMET NOTES.

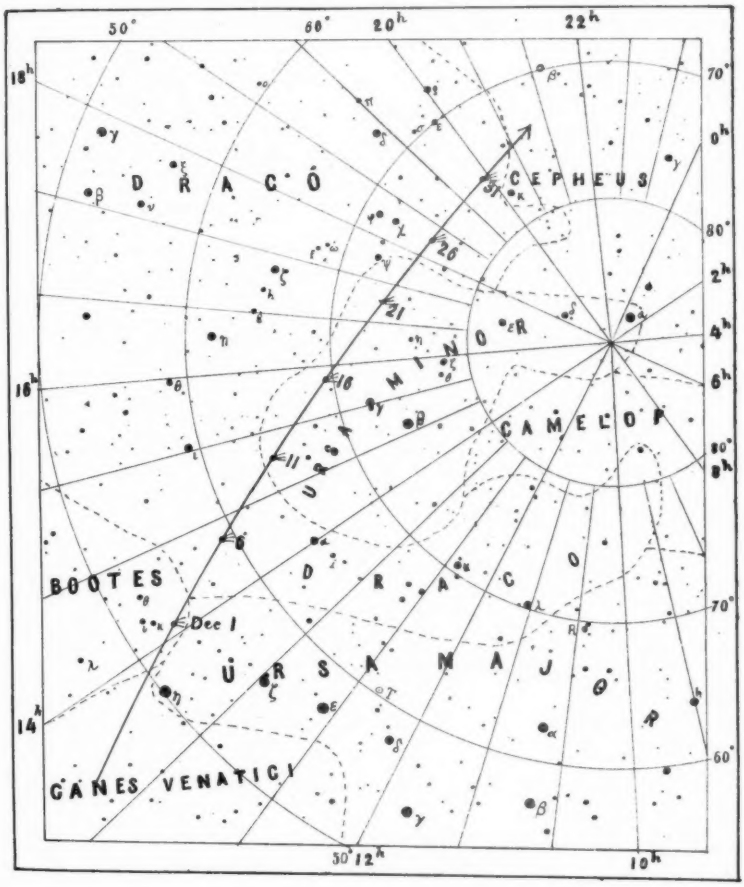
Elements and Ephemeris of Comet *c* 1893.—I send you herewith elements and ephemeris of Comet *c* by Mr. Phillips Isham and myself.

T = Sept. 19.3055 Berlin M. T.
$\Omega = 174°\ 54'\ 21''$
$i = 129\ 47\ 44$ } 1893.0
$\omega = 347\ 33\ 10$
$\log q = 9.91033$

Berlin midn.		α app. h m s	δ app. ° ′	log Δ
Dec.	1.5	14 03 53	+ 53 15.1	0.119
	2.5	08 27	54 23.9	
	3.5	13 15	55 32.7	0.118
	4.5	18 21	56 41.4	
	5.5	23 44	57 50.0	0.117
	6.5	29 25	58 58.4	
	7.5	35 25	60 06.2	0.118
	8.5	41 48	61 13.2	
	9.5	48 35	62 19.4	0.119
	10.5	55 50	63 24.8	
	11.5	15 03 33	64 28.8	0.120
	12.5	11 48	65 31.0	
	13.5	20 36	66 31.9	0.122
	14.5	29 59	67 31.7	
	15.5	40 03	68 29.0	0.125
	16.5	50 52	69 23.4	
	17.5	16 02 26	70 15.3	0.130
	18.5	14 47	71 04.4	
	19.5	27 57	71 50.2	0.136
	20.5	41 59	72 32.4	
	21.5	56 50	73 10.7	0.143
	22.5	17 12 30	73 45.0	
	23.5	28 57	74 14.9	0.149
	24.5	46 06	74 40.2	
	25.5	18 03 43	75 00.5	0.156
	26.5	21 34	75 16.1	
	27.5	39 38	75 26.5	0.164
	28.5	57 53	75 32.5	
	29.5	19 15 53	75 33.8	0.172
	30.5	33 28	75 30.7	
	31.5	50 33	+ 75 23.3	0.181

J. G. PORTER.

Comet Brooks (*c* 1893).—This comet, discovered by the writer on Oct. 16, has been observed on every possible occasion, and we have been favored with an unusually fine autumn in this locality—unusual in the great number of clear days and nights. Although the comet had passed perihelion at the time of discovery, it has held its light well, and has been a conspicuous telescopic comet. On the morning of Oct. 21, 17^h, the comet appeared brighter than at any previous observation. The tail could be easily traced to a distance of 3½°.



PATH OF COMET *c* 1893 (BROOKS) THROUGH THE CONSTELLATIONS FOR DECEMBER.

Some interesting changes have been noticed in the shape and structure of the tail. Its normal appearance might have been called straight, but on the morning of Oct. 21, 17^h (when the comet appeared at its brightest here), there was a sharp curve in the tail close to the head towards the south, and a faint secondary tail was seen issuing from the head at an angle of 30° to the main tail towards the north.

Bright moonlight then interfered for several days, but when the comet was

seen again, on Nov. 4, its tail had assumed its usual straight form with only slight curvature towards the extreme end. On Nov. 9, 17^h, however, another decided and interesting change was detected in the formation of the tail. It was straight for a length of half a degree from the head, where it became forked, the larger portion curving gracefully to the south, the fainter part straight or nearly so, branching to the north, the two branches making an angle with each other of about 25°. The comet on this occasion was bespangled with numerous small stars, forming altogether a most charming telescopic picture.

WILLIAM R. BROOKS.

Smith Observatory, Geneva, N. Y., Nov. 14, 1893.

PRACTICAL SUGGESTIONS.

It is thought best to give some space each month to queries and answers pertaining to astronomical themes. Contributors are requested to remember this corner and to write briefly and frequently for it.

2. Are the rising and the setting of the heavenly bodies the same in Eastern time as in Central? M. B. T. H.

Answer: The times of rising and setting of planets at any given place would be one hour later by Eastern than by Central time. The times given in our tables for these phenomena are local times for places in latitude 44° 28′, and are practically the same for the whole of theUnited States.

3. In the case of phenomena that do not depend on the rotation of the Earth, as the minima of Algol, is the longitude of the place necessarily considered? M. B. T. H.

Answer: No.

4. Given a 4-inch telescope, so good that it will easily resolve α Scorpii, or α Lyræ with a power of 95, and will separate π Arquilæ (1″.7), or ε Arietis (1″.3) with a power of 180 on any good night. If the above aperture be cut down to 2 inches by an annular diaphragm, it will resolve Rigel with a power of 95, If a stop be applied cutting out the central 2 inches, the glass will resolve Rigel with difficulty. A central stop cutting out 2¾ inches, but exposing a margin of more than twice the area of the first central two inches will fail to resolve Rigel. Do all good objectives suffer in like degree from uncorrected spherical aberration? The above seems to indicate that the central 2 inches of a 4-inch glass will resolve more than a whole 3-inch objective, especially on a bright object. S. G. S.

Answer:—In answering this question, I would say that there is some ambiguity about the question itself. That a central 2″ area of a high class objective should do better work than the whole of a 3″ high class objective is utterly impossible. The only thing that it would indicate is that there is something wrong with the 3″ objective. Diaphragms will not improve a first class objective, the fact of the matter is that the old fashioned way of testing the goodness of an objective is possibly good enough for one that has spherical aberration, but I have all along insisted that it is not the way to test a first class objective.

It is true that to explain the reason why to an amateur, is rather a difficult matter as it involves the phenomena of interference which in a teleseope is a function of the limiting aperture.

If the objective of S. G. S. is a first class objective the reason that it will not show companions to stars with an annular ring of the objective exposed, is that the limiting aperture gives extra thickness to the diffraction rings and robs the star discs of the light that would otherwise go into them.

I have always insisted, and in this I believe I have the best observers on my side, that a thoroughly corrected objective will always show more with its full aperture than when diaphramed down. J. A. B.

5. What are the practical difficulties in the way of better eyepieces? Do not expert opticians prefer to temper the objective to the eyepiece rather than to attack the latter and attempt to improve it? The negative eyepiece is fair, but is it not much behind objectives in perfection? S. G. S.

Answer: In answer to this question I might say that there is no difficulty in

the way of making good eyepieces for telescopes, although I find that the best observers prefer to use the good old fashioned Ramsden positive and Huygenian negative eyepiece. For high powers, indeed for all negative eyepieces above ¾ inch equivalent focus, the writer prefers the solid eyepiece. They give nearly one-third more light, have but two surfaces to reflect the light back again, and the definition in the center of the field with a good objective is of the highest class.

He would be a sorry optician who would "temper the objective to suit the eyepiece." I know such a method has been advocated, but what if you temper an objective to suit the various kinds of eyepieces used? The optician would have a more difficult contract to fulfil than he now has, and as it is the conditions are difficult enough. J. A. B.

6. There is a faint star in Cassiopeia not far from $\varkappa$, the location of Tycho's Nova, as given by Dr. Klein which I have been watching for a week, and can find nothing to correspond with it in Klein's map and D'Arrest's chart. Is it not worth the while of observers to examine it? Its position roughly is 30′ right ascension and 63° 20′ declination. B. F.

Answer: A photograph of the constellation Cassiopeia taken at Northfield, Sept. 21, with the 2½-inch camera shows no star brighter than 8 or 9 magnitude near the places of Tycho's Nova. See also page 166.

7. What is the latitude and the longitude of Goodsell Observatory, Carleton College?

Answer: Latitude $= +44° 27' 41''.6$; longitude $= 6^h 12^m 35^s.86$ west from Greenwich.

8. Would it not make your predictions of current celestial phenomena more valuable to the average person if reduced to Central Standard time?

Answer: The times of all the phenomena are reduced to central time except the times of rising and setting of the planets and those of occultations. The times of rising and setting depend upon the location of the observer and the central times of these are different for every different longitude, while the local times are practically the same for all places in nearly the same latitude. To obtain the standard times the observer has only to apply the reduction from local to stand, ard time for his own place.

The times of occultations vary so much, because of parallax, as seen from different places, that we have not thought it worth the while to reduce them to standard time, which would be correct only for Washington.

9. Will you kindly inform me through your question and answer column, what is the exact course of the light rays through a photographic portrait lens? No books to which I have access give a satisfactory diagram. I am using a Darlot lens of this description for stellar photography, and it is of course important to take advantage of the full aperture. The question has arisen, whether there is a loss of light from the fixed diaphragm between the lenses. I suppose that there is no doubt that the definition of an ordinary commercial lens is improved by it, but is there not a certain loss of light, even if its aperture is as great as a section of the cone of rays from the front lens. My "Shoptician," as Leckey calls a mere dealer in optical wares, insists that the rays cross between the lenses and that therefore quite a small stop may be used at the point of intersection. This seems to me to be nonsense, as the focus of the front lens is more than ten times as long as the distance between it and the diaphragm referred to, and yet I confess that I do not see why the back lens should have an aperture nearly as great as that of the front, unless its large aperture is intended to subserve some useful purpose.

I am also doing some photographic work with an enlarging lens, attached to my telescope and should be grateful for a formula to obtain the magnification of a given projection, *e. g.*, if I use an enlarging lens of 2-in. *e. f.* with an objeet glass of 70 inches focus, at what distance should the screen be placed to obtain a magnification of ten diameters? Is the practice of measuring the image of the Sun, on a photographic plate taken at the principal focus, and comparing this diameter with that of the enlarged projection a correct one? P.

(1) Regarding "the exact course of the light rays through a photographic portrait lens," there are two ways in which the subject may be approached.

All that happens to a ray of light, on passing through a portrait lens, is sim-

ply a series of successive refractions at successive spherical surfaces. The law of refraction at a single spherical surface is given in all the elementary books. As a first method, then, the inquirer may trace the ray through the crown, into the flint, then into the space between the front and back lenses and again through the flint and crown into the air. To do this accurately one must know the radii of curvature and the refractive indices of the lenses. He must also know the relative position of the separate lenses as well as the direction and point of incidence of the incident ray. But, if the focal lengths of the front and back lenses are each known, there is no difficulty in tracing the ray in a sort of general way without any more exact information, remembering simply that the back lens receives a cone of rays which have had new directions impressed upon them by the front lens.

The back lens, in turn, makes this cone still more convergent, so that the apex of the cone falls on the ground glass, when the instrument is properly focused.

A second, and vastly more elegant, method of treating such a lens is that introduced by Gauss. The beauty of his treatment is that it disregards at once and entirely the actual path of the ray in the glass. He determines four points on the optical axis of the lens—the so-called cardinal points. These being once determined, the path of any emergent ray is determined immediately and simply from the path of the incident ray. Space does not permit us to go into further detail than to say that two of these cardinal points are the two principal foci of the lens and that the other two are known as the "principal points" of the lens. These latter are defined by this remarkable property, *viz.*, that an object placed at one of the principal points will give an *erect* image of the *same size* at the other principal point.

Any one who cares to look into this matter further will find the matter discussed in an elementary way in Pendlebury's "*Lenses and Systems of Lenses:*" also in Heath's *Geometrical Optics.*

(2) In answer to the second inquiry, it is to be noted that in general the use of a diaphragm occasions a loss of light. But, in the particular case mentioned, where the aperture of the stop is as great as the section of the cone of rays at that point, of course there can be no loss of light.

It must not be forgotten, however, in this connection, that the diameter of the stop is not the same as the effective aperture of the lens when used with this stop.

Not only does a stop in general produce a loss of light, but it also changes the distribution of light on the ground glass, diminishing the intensity near the edge of the plate.

(3) As to the necessity for a large aperture in the rear lens, this is not avoided by the use of a small stop. For, consider a bundle of rays coming from any point on the extreme right of the field. This bundle will pass through the right hand edge of the front lens, then through the small stop, and lastly through the left hand edge of the rear lens.

No two rays from any real point will intersect between the front and back of a portrait lens. Such an intersection occurs only at some focus. But, certainly, rays from different points of the field will cross each other in the plane of the diaphragm.

(4) As to the magnifying power of an enlarging lens, this is given immediately by the ratio of the focal length of the combination to the focal length of the objective.

By "focal length" is here meant the true focal length and not the so-called "back focus."

The only question involved is, then, the determination of the focal length of the combination. Let us call this quantity F. Then

$$F = -\frac{F_1 F_2}{D}$$

where $\begin{cases} F_1 = \text{true focal length of objective.} \\ F_2 = \text{true focal length of enlarging lens.} \\ D = \text{distance between second principal focus of objective and first principal focus of enlarging lens.} \end{cases}$

D is positive when the two lenses are separated by a greater, and negative when they are separated by a less, distance than the sum of their focal lengths. In the case of the ordinary astronomical telescope, when adjusted for eye observations, $D = 0$.

Knowing F, we now know the magnifying power of the combination. It remains to find the position at which the screen or ground-glass must be placed: in other words, we must find the "back focus" of the combination.

But this is easily done, for we have only to add to the true focal length the quantity C, in order to obtain the "back focus," where very approximately

$$C = \frac{F_2 (D + F_1 + F_2)}{D}$$

In the particular lens cited in the inquiry, the writer does not state whether the enlarging lens is negative or positive. In order to show the application of the above formulæ to his case we shall assume that he is using a double concave, as in the ordinary telephotographic combination.

Then we have given

$$F_1 = + 70 \text{ inches}$$
$$F_2 = - 2 \text{ "}$$
$$\text{Magnifying power} = 10$$

Hence

$$F = F_1 \times \text{magnifying power} = 70 \times 10 = 700 \text{ inches}$$

$$D = + \frac{70 \times 2}{700} = + 0.2 \text{ inches}$$

and

$$C = - \frac{2 (0.2 + 70 - 2)}{0.2} = - 682 \text{ inches.}$$

Adding this correction, C, to the true focal length of the combination, 700 inches, we have 18 inches as the "back focus" of the system. In other words, the system will magnify ten times when the ground-glass is 18 inches behind the rear lens and the rear lens is $(2 - 0.2) = 1.8$ inches in front of the principal focus of the first lens. This result agrees, as will be seen, with the general rule that the magnifying power of any lens is the ratio of the distances of the image and object from the center of the lens. H. C.

GENERAL NOTES.

Patrons will please notice the first page of the advertisements which gives some idea of the circulation of this new periodical.

The wide area that our circulation covers is largely due to the favorable and generous notice that the press has given of POPULAR ASTRONOMY very generally at home and abroad.

Goodsell Observatory has just received a new photographic camera; lenses 6-inches clear aperture and focal-length 30-inches, giving a field of view in the sky of 16½° in diameter. The curves of the lenses were computed by Professor C. S. Hastings, of Yale University, the grinding and polishing was done by J. A. Brashear of Allegheny, Pa., and the mounting was made by Warner & Swasey, Cleveland, Ohio.

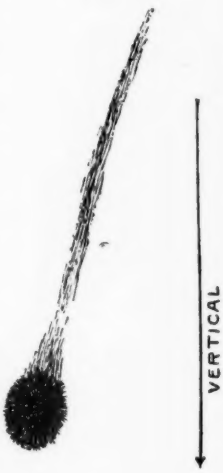
POPULAR ASTRONOMY will soon give some fine pictures of celestial objects from photographs made by this new camera.

Peculiar Phenomena.—About 10 o'clock P. M., central standard time, Nov. 18, there appeared in the north a *fire-red streak* of marked brilliancy. It began about 10° above horizon and extended about 15° or 20° exactly in the meridian so far as could be judged by observation.

It was not over a degree or so wide, with its edges sharply marked. There was only one streak and it maintained its position in the sky and its length and breadth for the 15 minutes that it was observed. Its brilliancy remained a con-

stant to the end except that a *very slight* reddish haze seemed to form about the lower end of the streak. Its sharpness of outline was perhaps magnified by the background of floating dark clouds. No one to my knowledge saw it form; it melted away very suddenly. To my mind it seemed like a most intense electrical discharge, like a gigantic Geissler tube. There was no flickering, no wavering, but it was constantly steady. R. L. SACKETT.

Meteor in Daytime.—Miss E. M. Bardwell, South Hadley, Mass., has given us an account of a meteor seen at the above named place at 10 o'clock A. M., Standard Eastern Time, in the N. N. W., about 25° above the horizon, moving nearly vertically downward, in a path slightly curved and about five degrees long. The meteor was of a beautiful green color, somewhat elongated and sharply defined, the shortest diameter about one third that of the moon; motion slow. There was considerable haze in the atmosphere with some white floating clouds at the time, yet the meteor was seen by several students on the way to recitation while they were going N. N. E. It is remarkable that the meteor should have been seen under such circumstances and especially that the break in the train should have been noticed as shown in the accompanying cut.



Brilliant Meteor.—At 7.12 (E. time) this evening, a brilliant meteor was observed just east of the moon, moving in a south westerly direction. It passed near β. Capricorni and disappeared, below Altair, 30° from horizon, covering, I should judge, about 70° of the sky, and occupying 3 seconds of time. The moon 12 days old, was clear and bright rendering it difficult to locate the exact path or point of disappearing. The meteor was of a deep *bluish hue*, slightly pear-shaped, with no trail and apparently larger and brighter than Jupiter, then above E. horizon. Just before disappearing a fragment separated from its northern side, (no report heard), moving in same direction but gradually dropping behind, this was of a decided *orange* tint, and vanished from view a trifle earlier than the larger one. J. C. SANFORD.

Marblehead, Mass., Oct. 21st, 1893.

The November Meteors.—The Leonid meteor radiant was photographed on the mornings of Nov. 14 and 16, with the 2½-inch Darlot lenses of Goodsell Observatory. Two exposures were made on the morning of the 14th, the one from 3^h 50^m to 5^h, the other from 5^h to 6^h. The field covered by the plates is 24° in diameter, ζ Leonis being placed in the center. The first plate on the 14th shows one meteor trail near the star $\varkappa$ Leonis. It is about 1° long and points exactly toward the Leonid radiant. It is near the edge of the plate where the definition is poor, so that it is not well shown. The other plates show no trails at all. I saw but few meteors while the exposures were being made, and no very bright ones. The few Leonids I did see moved so swiftly that it is doubtful whether their trails would have been impressed upon the plate had they been within the range of the camera. H. C. W.

November Meteors.—The November meteors were far more abundant this year than I have ever seen them before. Especially were they plentiful on the mornings of November 13, 14, and 15. Many very brilliant ones were seen. One on the morning of the 14th burst just below Coma Berenices. It was nearly as large as the full Moon. On November 15th at 14^h 50^m a splendid meteor from Leo shot across the sky and burst between Zeta and Eta Ursæ Majoris. This left a persistent train about 10° long which remained bright and straight for about five minutes—like a slender comet—it then collected into a cloudy mass at the point of explosion. This elongated mass of luminosity remained distinctly visible for half an hour, drifting due east in the meantime about 7°. As I was photographing the comet at this time I could not turn my telescope to it to see how long it remained visible after it had ceased to be seen with the naked eye.

Mt. Hamilton, Nov. 19, 1893. E. E. BARNARD.